Applied Superconductor Limited

Superconducting Fault Current Limiter

33kV SFCL Design Report

Milestone 4

CONFIDENTIALITY (Confidential or not confidential) :NOT **CONFIDENTIAL**
PROJECT OR PRODUCT : 33kV 800A normal current; 1400A/15mins overcurrent design

UNIT APPROVAL	**Name**	**Date**
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REVISION HISTORY RECORDS

Revision	**Date**	**Creation / Update summary**
Issue 1	07.03.2012	Customer Issue
Issue 2	30.03.2012	Customer Issue with modified bushing layout (new Part 3)

TABLE OF CONTENTS

1. INTRODUCTION

This report details the design of the SFCL for Jordanthorpe SGSP. The report comprises six parts as follows:

Part 1 This document which discusses the design in the context of the current plans to proceed with the installation at Jordanthorpe and the current estimations of the electrical characteristics.

Part 2 ZP-ES2012-003 Rev A, Sheffield Ring Jordanthorpe Supply Point, 33kV FCL Design. This document presents the engineering calculations supporting the design approach taken.

Part3a -2012-0004rev06. This comprises arrangement (modified) drawings of the SFCL.

Part 4 ZP-ER2011-002 Rev B, ASL Sheffield Fault Current Limiter Model, which presents the results of modelling the SFCL performance in P-SCAD, using a FORTRAN subroutine.

Part 5 ZP-ES2011-014 Rev B, Sheffield Ring Jordanthorpe Supply Point 33kV FCL, Testing Protocol.

Part 6 Jordanthorpe Proposed Layout - Y432A5104A - 20.6.11. Drawing showing arrangement and balance of plant at Jordanthorpe site.

2. PROPOSED INSTALLATION LAYOUT

2.1 Local Network

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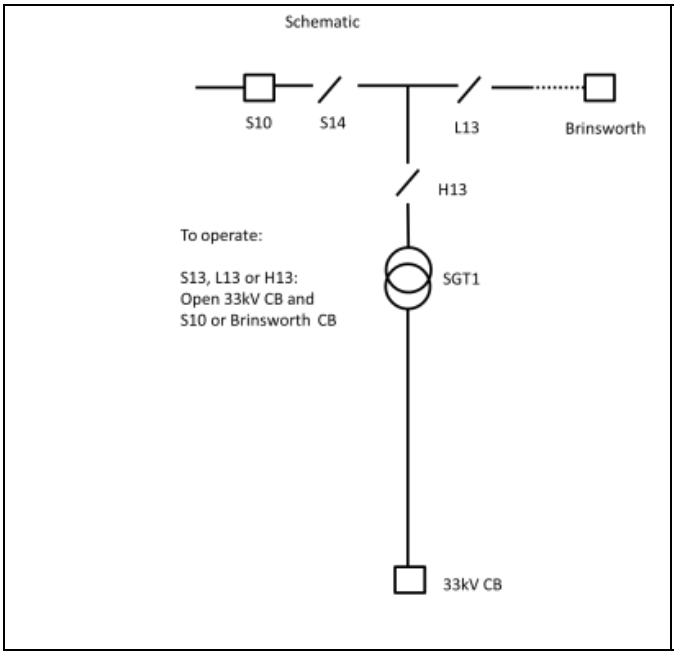
<td> 
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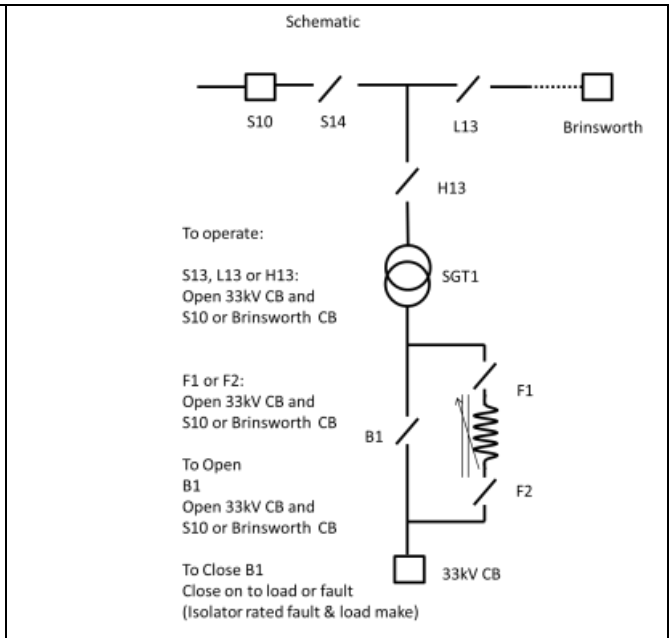
<td> 
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<tr>
<td>Substation as is</td>
<td>Substation with FCL</td>
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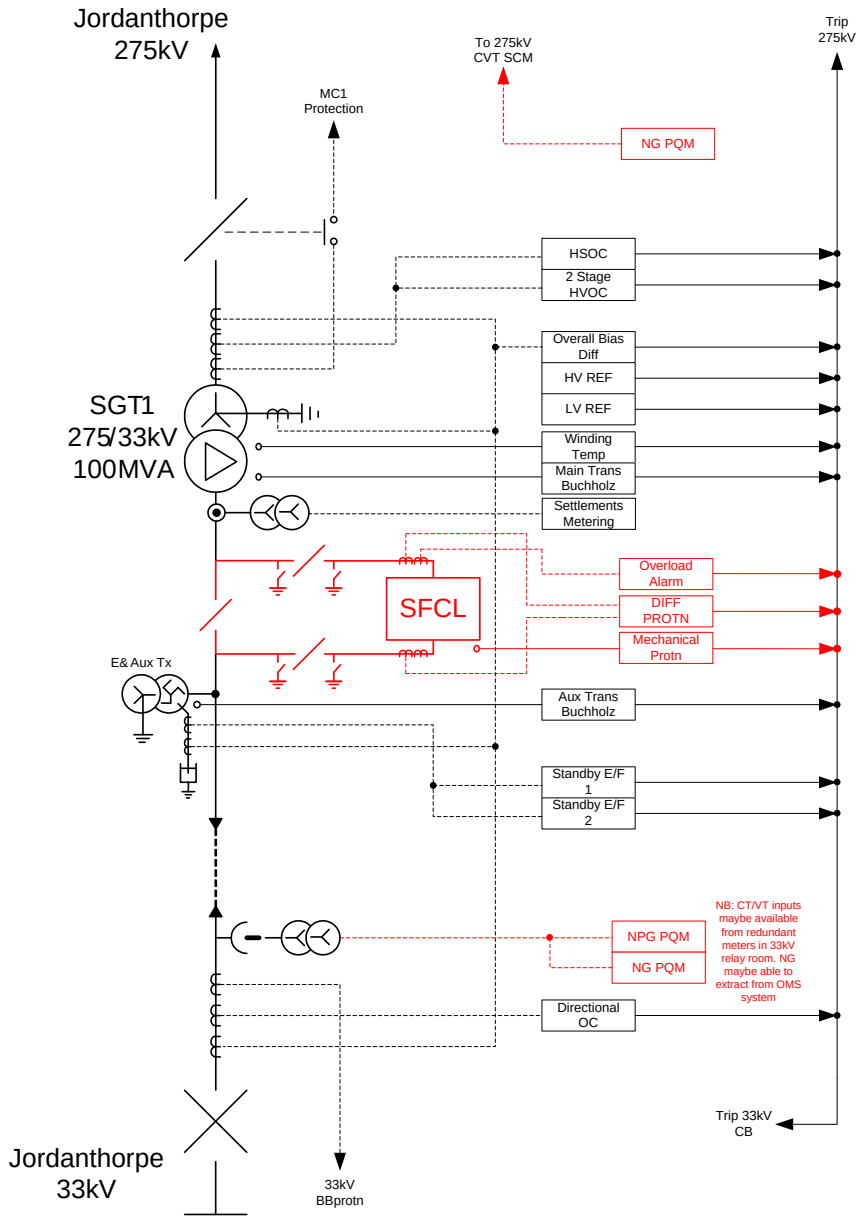
2.2 Protection

The Jordanthorpe SGT1 transformer and feeder is protected by a Restricted Earth Fault (REF) system and a Standby Earth fault (SEF) system. Putting the FCL into this protected zone would also protect the network from it, however the detection time for the fault (is it the FCL/is it the (unmaintained) SGT1?) would take more diagnosis than present. A fast acting Solkor type circuit fitted round the FCL would give indication of the Fault position. This would need double ingoing/outgoing CTs at the FCL which are going to be difficult to mount on the isolator structure. Mounting them into the FCL would be better. ASL to raise this with Zenergy.

The normal practice would be to put in new zones to protect "to the SFCL", "the SFCL" and "from the SFCL". Bypass arrangements make this complicated.

An overcurrent (>800A) relay will also need to be added to the design to trigger the bypassing of the FCL.



2.3 Site Physical Layout

Please refer to Part 6 of this Report <Jordanthorpe Proposed Layout - Y432A5104A - 20.6.11>

3. SFCL PERFORMANCE

3.1 Specification

The SFCL specification has been modified since the Milestone 3 (Network Impact) report in that the normal current rating of 800A continuous is unchanged, but the overload capacity has been reduced from 2000A continuous to 1400A for 15 minutes.

The revised specification is given in Part 4,< ZP-ER2011-002 Rev B, ASL Sheffield Fault Current Limiter Model> and is repeated here:

Parameter	Requirement
Rated voltage	36kV
Line frequency	50Hz
Line voltage at fault level below	33kV
Maximum allowable steady state voltage drop at rated continuous normal current (800A)	600V rms
Lightning impulse voltage withstand level	170kV; 1.2/50μs
Power frequency voltage withstand level	70 kV for 1 minute
Continuous normal current	800Arms
Maximum normal current (magnitude and duration)	$1400A_{rms}$ 15 minutes
Prospective peak fault current	$23\ kA_{peak}$
Peak limited current	$<13.6\ kA_{peak}$
Prospective symmetrical fault current	$8.4\ kA_{rms}$
Symmetrical limited current	$<5kA_{rms}$
Fault duration	Up to 3 seconds
Reclosure sequence (if applicable)	N/A
Transformer Impedance (ohms)	R 0.065231 XL 2.27057
Feeder X/R; Asymmetry Factor	34.808 2.706
Typical test laboratory X/R	60
Load power factor	0.98
Size or weight constraints (if applicable)	N/A (yet)

The current limiting performance above is based on data submitted to Zenergy Power in 2009. The fault level situation at Jordanthorpe has become less onerous according to a study performed in 2011.

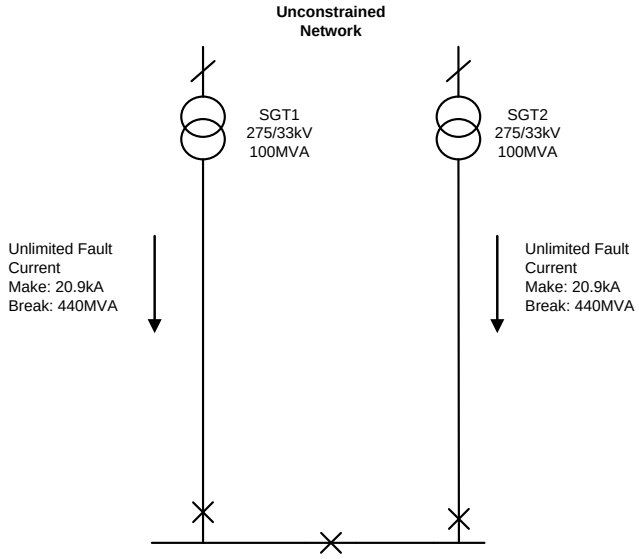
3.2 Current Limiting Performance

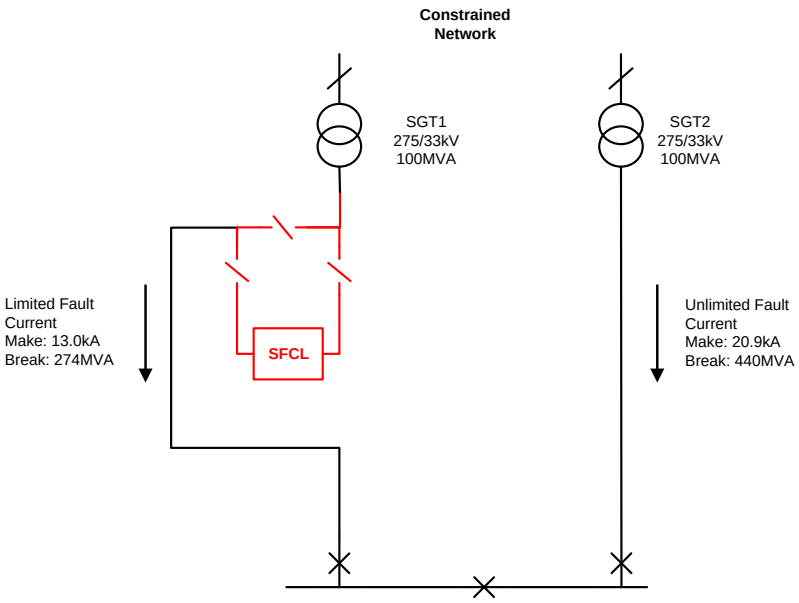
Fault level estimated in 2011:

Based on the 2011 Fault Level Survey the fault levels for the 33kV system are 846MVA break and 42.2kA make. The installed switchgear has a 3-phase break rating of 1000MVA and a make rating of 43.7kA.

It is anticipated that the SFCL will limit the fault level to 714MVA break and 33.9kA make by restricting the fault contribution from one transformer.

The Network contribution from both transformers together is 880MVA break and 41.8kA make. A single transformer provides 440MVA break and 20.9kA make. To achieve a break rating of 714MVA and make rating of 33.9kA one transformer needs to be limited to 274MVA break and 13.0kA make as follows:





The current limiting performance in the Zenergy specification is summarised below:

Prospective peak fault current	23 kA$_{peak}$

Peak limited current	<13.6 kA$_{peak}$
Prospective symmetrical fault current	8.4 kA$_{rms}$
Symmetrical limited current	<5kA$_{rms}$

The performance required in 2011 is as follows:

20.9kA $_{peak}$ prospective reduced to 13.0kA $_{peak}$ = 38% limiting

440MVA prospective reduced to 274MVA

7.7kA $_{rms}$ prospective reduced to 4.8kA $_{rms}$ sym = 38% limiting

Zenergy Specification 2010

23kA $_{peak}$ prospective reduced to 13.6kA $_{peak}$ = 41% limiting

480MVA prospective reduced to 285MVA

8.4kA $_{rms}$ prospective reduced to 5kA $_{rms}$ sym = 40% limiting

It is highly likely that an SFCL designed to the Zenergy Specification performance levels will achieve the 2011 requirements for Jordanthorpe SGSP. Whilst testing is specified based on the original specification in Part 5 of this Report, ASL will recommend that the test levels be adjusted slightly to correspond to the current fault level situation at Jordanthorpe.

4. SFCL DETAIL DESIGN

The design details are given in the following:

Part 2 ZP-ES2012-003 Rev A, Sheffield Ring Jordanthorpe Supply Point, 33kV FCL Design. This document presents the engineering calculations supporting the design approach taken.

Part3 0004 Rev 02, Sheffield Ring Jordanthorpe Supply Point, 33kV Layout Preliminary. This comprises arrangement drawings of the SFCL.

Part 4 ZP-ER2011-002 Rev B, ASL Sheffield Fault Current Limiter Model, which presents the results of modelling the SFCL performance in P-SCAD, using a FORTRAN subroutine.

Part 5 ZP-ES2011-014 Rev B, Sheffield Ring Jordanthorpe Supply Point 33kV FCL, Testing Protocol.

5. CONCLUSION

This report details the 33kV SFCL design for Jordanthorpe SGSP.

End of Report