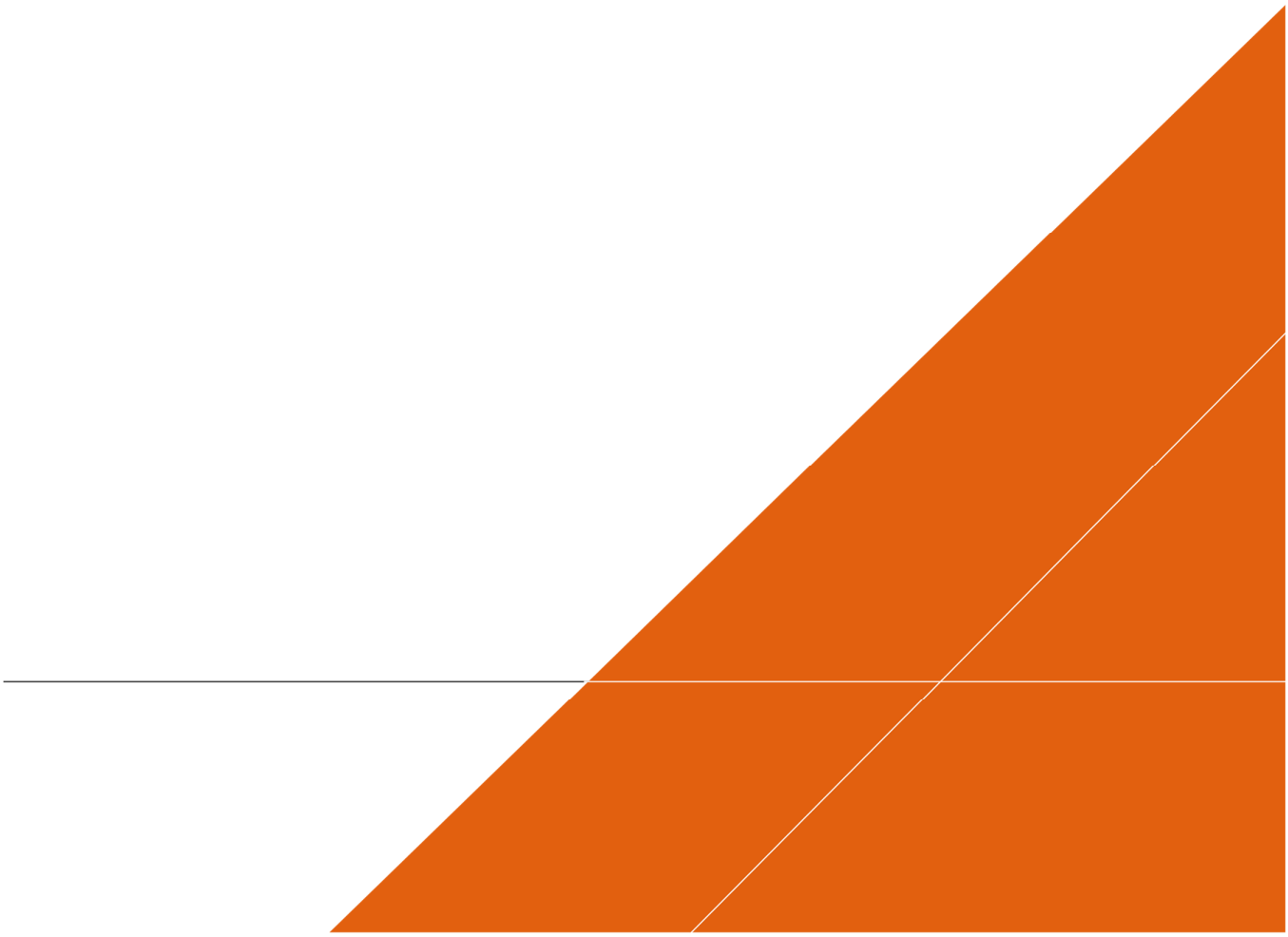
ARCADIS Design & Consultancy for natural and built assets

REDHOUSE LIVE TRIAL

Protection Settings

10048782/R/PW/02

AUGUST 2021



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REDHOUSE LIVE TRIAL

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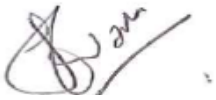
Checker	Joanne Evans	
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Executive Summary

The conclusions and recommendations of the study looking at the protection associated with performing a black start from distributed energy resources (DER), specifically from Redhouse Battery Energy Storage System (BESS), are detailed below:

Conclusions

This report documents the protection limitations and changes required for the 33 kV and 132 kV protection systems for the black start condition fed via Redhouse Battery Energy Storage Scheme due to the reduction in fault levels at these voltage levels.

The extent of the changes were determined by the level of grading that is required and the fault clearance times required to protect equipment. For the trial, grading between devices on the 33 kV DNO system and the 33 kV BESS system were not considered. As the trial system will not be loaded the protection settings provided were set to ensure operation of the devices for the reduced fault levels.

Settings for the trial are provided in Appendix C.

The main limitations in going forward with the BESS system supplying for a black start would be the differentiation of load current and fault current. This can be done on the 33 kV system using voltage- controlled overcurrent but requires a voltage signal to determine a fault condition. This function is available on the 33 kV feeders but not on the transformer 33 kV protection device.

The main limitation with the 132 kV system is the reduced fault level is not sufficient with the BESS system only to operate the line differential protection or for voltage-controlled overcurrent protection as the pickup for the voltage control can only be reduced to the pickup setting of the relay, in this case 40 A for a 500/1 A CT. The 132 kV system is limited by the CT ratio and settings available on the devices. Therefore 132 kV phase faults may not be detected.

In summary the existing protection at 33 kV and 132 kV is limited and not adequately protecting the system for faults during black start. Consideration should be given to UV and OV protection on the BESS (i.e. its G99 protection) this could be used to detect additional asymmetric faults. Consideration should also be given to setting the negative sequence NPS overvoltage (ANSI 47) protection on the BESS G99 protection. The NPS voltage distortion is higher the smaller the NPS current is so this would offset some uncertainty in the way the NPS current has been modelled allowing detection of more fault conditions.

1 Introduction

SP Transmission requested[1] Arcadis Consulting (UK) Ltd ("Arcadis") to provide a quotation for studies to identify the protection limitations and changes required for the proposed Redhouse Live Trial.

This will include 'local' testing on the Redhouse Battery Energy Storage System (BESS) network, and energising a section of the Redhouse GSP distribution network, and the associated transmission network, when supplied from the Redhouse BESS in both grid following (along with a diesel generator) and grid forming mode.

The scope of work required is defined within the tender document[2] in terms of technical outputs. A SPEN DIgSILENT PowerFactory model of the relevant distribution networks (modelled to the primary substation 11 kV busbars); along with the associated transmission networks has been provided. In addition, a data sheet with fault infeed data of the Redhouse BESS has been provided. This was also provided as a model in PowerFactory.

[1] Email from N. Miller (SPT) to P.Watson (Arcadis), 'D ReStart – Redhouse RFP',16/03/2021

[2] Request for Proposal for Consultancy Services Distributed ReStart REP REDH01 Rev 1 Dated 15/03/2021

2 Scope of Work

The scope of work required is defined within the tender document[2] in terms of technical outputs. SPEN can provide a DIgSILENT PowerFactory model of the relevant distribution networks (modelled to the primary substation 11 kV busbars); along with the associated transmission networks. SPEN will also provide protection policy documents and existing settings as required along with relevant information from third parties where necessary.

The network under consideration in this report is Work Package 2 and 4 (WP2 & WP4).

3 Applicable Standards & Legislation

This section outlines any relevant standards or legislation which may be applicable under black start conditions with respect to protection.

3.1 Protection

3.1.1 ESQCR

The Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) regulation 6 (electrical protection) states:

> *"A generator or distributor shall be responsible for the application of such protective devices to his networks as will, so far as reasonably practicable, prevent any current, including any leakage to earth, from flowing in any part of his network for such a period that that part of his network can no longer carry that current without danger."*

3.1.2 SP Policy Documents

Protection functionality and settings reviewed in this report are based on the ScottishPower protection policy documents. The requirements of these policy documents are described in more detail in Section 6. The following policy documents are used as the basis of this report.

- PROT-01-006 Issue 6 - 33kV Protection and Control Application Policy
- PROT-01-107 Issue 6 - 132kV Protection and Control Application Policy
- PROT-01-009 Issue 4 - Protection and Control Setting Policy
- PROT-01-012 Issue 2 - 11kV Protection and Control Application Policy
- PROT-01-014 Issue 2 - 11kV and 6.6kV Protection and Control Settings Policy
- PROT-03-020 Issue 10 - Technical Specification for 33kV Protection and Control Equipment
- PROT-01-008 Issue 6 - 400kV and 275kV Protection and Control Application Policy

3.1.3 EREC G59

Typical voltage, frequency, LOM and vector shift protection settings taken from G59 are shown in the extracts below. Generation commissioned on or after 27th April 2019 must comply with EREC G99 and EREC G59 is not applicable to generation commissioned on or after that date.

	Small Power Station				Medium Power Station	
	LV Protection$		HV Protection$			
Prot Function	Setting	Time	Setting	Time	Setting	Time
U/V st 1	Vφ-n† - 13% = 200.1V	2.5s*	Vφ-φ‡ -13%	2.5s*	Vφ-φ‡- 20%	2.5s*
U/V st 2	Vφ-n† - 20% = 184.0V	0.5s	Vφ-φ‡ - 20%	0.5s		
O/V st 1	Vφ-n† + 14% =262.2V	1.0s	Vφ-φ‡ + 10%	1.0s	Vφ-φ‡ + 10%	1.0s
O/V st 2	Vφ-n†+ 19% = 273.7V	0.5s	Vφ-φ‡ + 13%	0.5s		
U/F st 1	47.5Hz	20s	47.5Hz	20s	47.5Hz	20s
U/F st 2	47Hz	0.5s	47Hz	0.5s	47Hz	0.5s
O/F st 1	51.5Hz	90s	51.5Hz	90s	52Hz	0.5s
O/F st 2	52 Hz	0.5s	52Hz	0.5s		

RoCoF§ settings for Power Stations <5MW Registered Capacity		
Date of Commissioning	Asynchronous	Synchronous
Generating Plant Commissioned before 01/02/18	Not to be less than K2 x 0.125 Hz/s# and not to be greater than 1.0Hz/s¶#, time delay 0.5s	Not to be less than K2 x 0.125 Hz/s# and not to be greater than 1.0Hz/s¶#Ω, time delay 0.5s
Generating Plant commissioned on or after 01/02/18	1.0Hz/s¶#, time delay 0.5s	1.0Hz/s¶#, time delay 0.5s

RoCoF§ settings for Power Stations ≥5MW Registered Capacity				
Date of Commissioning		Small Power Stations		Medium Power Stations
		Asynchronous	Synchronous	
Generating Plant Commissioned before 01/08/14	Settings permitted until 01/08/16	Not to be less than K2 x 0.125 Hz/s# and not to be greater than 1.0Hz/s¶#, time delay 0.5s	Not to be less than K2 x 0.125 Hz/s# and not to be greater than 0.5Hz/s¶#Ω, time delay 0.5s	Intertripping Expected
	Settings permitted on or after 01/08/16	1.0Hz/s¶#, time delay 0.5s	0.5Hz/s¶#Ω, time delay 0.5s	Intertripping expected
Generating Plant commissioned between 01/08/14 and 31/07/16 inclusive		1.0Hz/s¶#, time delay 0.5s	0.5Hz/s¶#Ω, time delay 0.5s	Intertripping expected
Generating Plant commissioned on or after 01/08/16		1.0Hz/s¶#, time delay 0.5s	1.0Hz/s¶#, time delay 0.5s	Intertripping expected

Historic Vector Shift Settings			
Date of Commissioning	Small Power Stations		Medium Power Stations
	Asynchronous	Synchronous	
Settings permitted for **Generating Plant** commissioned before 01/02/18	K1 x 6 degrees	K1 x 6 degrees#	Intertripping Expected
Settings permitted for **Generating Plant** commissioned on or after 01/02/18	Vector Shift not allowed as LoM in these Power Stations		Intertripping Expected

3.1.4 EREC G99

Typical voltage, frequency and LOM protection settings taken from G99 are shown in the extracts below. These apply to connections on or after 27th April 2019.

Protection Function	Type A, Type B and Type C Power Generating Modules				Type D Power Generating Modules and Power Generating Facilities with a Registered Capacity > 50 MW	
	LV Protection(1)		**HV** Protection(1)			
	Trip Setting	Time Delay Setting	Trip Setting	Time Delay Setting	Trip Setting	Time Delay Setting
U/V	Vφ-n† -20%	2.5 s*	Vφ-φ‡ -20%	2.5 s*	Vφ-φ‡- 20%	2.5 s*
O/V st 1	Vφ-n† + 14%	1.0 s	Vφ-φ‡ + 10%	1.0 s	Vφ-φ‡ + 10%	1.0 s
O/V st 2	Vφ-n†+ 19%$	0.5 s	Vφ-φ‡ + 13%	0.5 s		
U/F st 1	47.5 Hz	20 s	47.5 Hz	20 s	47.5 Hz	20 s
U/F st 2	47.0 Hz	0.5 s	47.0 Hz	0.5 s	47.0 Hz	0.5 s
O/F	52.0 Hz	0.5 s	52.0 Hz	0.5 s	52.0 Hz	0.5 s
LoM (RoCoF)#	1 Hzs^{-1} time delay 0.5 s		1 Hzs^{-1} time delay 0.5 s		Intertripping expected	

3.2 Black Start

3.2.1 Distribution Code

The Distribution Operating Code section of the Distribution Code (DOC9.4 Black Start) states:

"During a Total Shutdown or Partial Shutdown and during subsequent recovery the Security Standards set out in, or deriving authority pursuant to, the Transmission Licence and the Distribution Licence may not apply and the Total System may be operated outside normal voltage and Frequency standards."

4 Island Earthing

A 33 kV Earthing Transformer is required since the 132/33 kV Redhouse Grid transformer, which provides the ground for the 33 kV system, will be isolated from the test network for Phase 1 tests. The hired equipment will be delivered in a contained network and will connect to the Redhouse BESS developer Greenspan's 33 kV system using spare 33 kV Circuit Breaker (CB) 2L5.

For Phase 2 tests with the wider network when the Redhouse Grid transformer is connected the earthing transformer is also connected on the network.

For the trial both earths should be connected in case a fault condition occurs and the grid transformer breaker is opened.

If the black start were to be progressed, then an auto-changeover between the earths could be arranged and in the case of a fault condition the generation inter-tripped.

5 Redhouse Network

5.1 Fault Level Model

The network model including the 11.6 MVA BESS was provided and studies carried out for work package 1 [22]. Figure 5.1 shows the Redhouse BESS model.

The parameters for the BESS transformer were updated in the DIgSILENT model based on the provided datasheet [22]. The impedance for the BESS transformer was modelled as 8.5% (5% - 8.5% provided in the datasheet) to give smallest fault levels (worse case fault current for protection setting).

The diesel generator was modelled assuming that it provides a maximum fault current of 3 x rated current. The diesel generator in the provided model was modelled as 3 parallel 1.25 kVA machines.

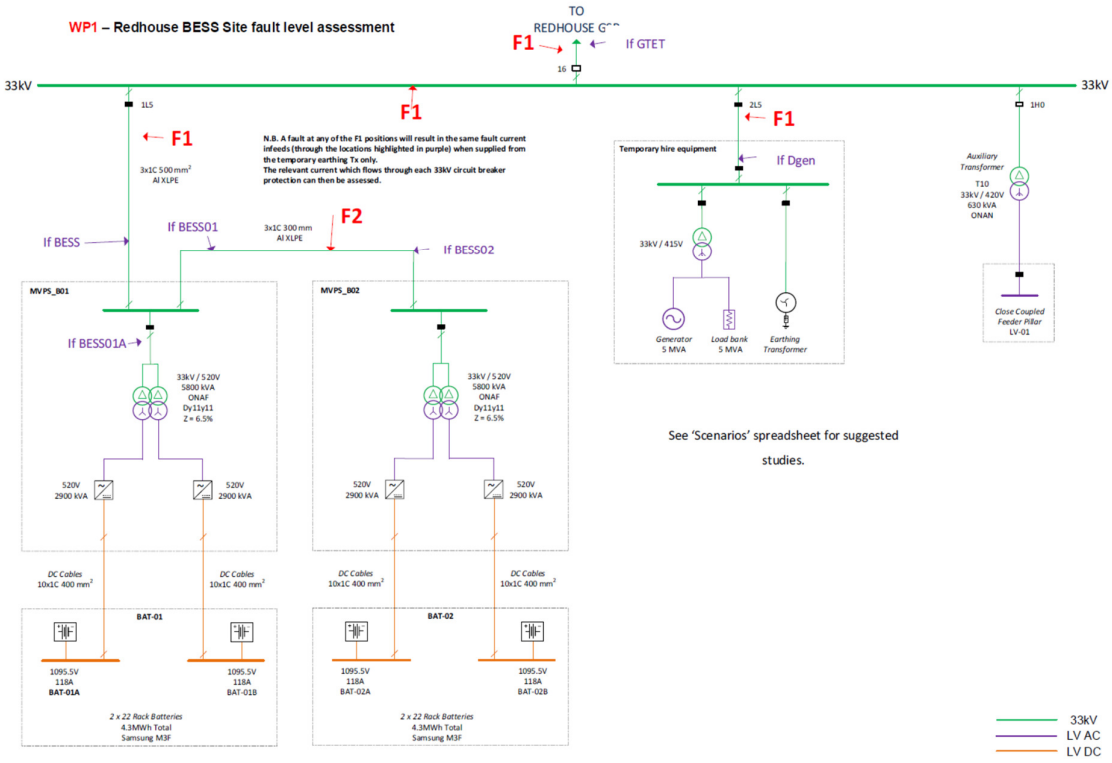


Figure 5.1: Redhouse BESS Model

5.2 Fault Level Calculation

Using the network model provided and the following island network configurations:

Scenario 5: Grid Forming, Diesel Generator off.

Scenario 8: Grid Forming, Diesel Generator on.

The three phase, line to line and earth fault levels at nodes below were calculated as shown in Tables 5.1.1.and 5.1.2. Fault levels are calculated at 1 s.

Location	Voltage	DIgSILENT Node Name	LLL I_{ks} (kA) SC5	LL I_{ks} (kA) SC5	LG I_{ks} (kA) SC5
Redhouse BESS 33 kV Busbar	33	REDH_BESS	0.213	0.368	0.641
Redhouse GSP 33 kV Busbar	33	REDH3A1	0.213	0.368	0.641
Redhouse Local Transformer 33 kV	33	REDHT1	0.213	0.368	0.641
Birrel Wynd Transformer 33 kV	33	BIWYT1	0.213	0.368	0.641
Chapel Transformer 33 kV	33	CHELT1	0.213	0.368	0.641
Redhouse	132	REDH1-	0.053	0.092	0.160
Glenniston	132	GLNI1-	0.053	0.092	0.160
Mossmorran	132	MOSM1B	0.053	0.092	0.160

Table 5.1.1 Calculated Fault Levels for Scenario 5

Location	Voltage	DIgSILENT Node Name	LLL I_{ks} (kA) SC8	LL I_{ks} (kA) SC8	LG I_{ks} (kA) SC8
Redhouse BESS 33 kV Busbar	33	REDH_BESS	0.386	0.565	0.790
Redhouse GSP 33 kV Busbar	33	REDH3A1	0.386	0.565	0.790
Redhouse Local Transformer 33 kV	33	REDHT1	0.386	0.565	0.790
Birrel Wynd Transformer 33 kV	33	BIWYT1	0.383	0.558	0.763
Chapel Transformer 33 kV	33	CHELT1	0.383	0.557	0.755
Redhouse	132	REDH1-	0.094	0.135	0.232
Glenniston	132	GLNI1-	0.094	0.134	0.231
Mossmorran	132	MOSM1B	0.094	0.134	0.231

Table 5.1.2: Calculated Fault Levels for Scenario 8

It is noted that the LL and LG faults are larger than the three phase contributions this is due to a high negative phase sequence current contribution from the modelled embedded generation.

6 Protection

The following sections look at the protection achieved at the fault levels calculated during the black start condition and determine whether changes to the relay settings or hardware changes are necessary to make the system 'Black Start ready'.

Where changes are necessary these have been specified. Where suitable changes cannot be made with the existing relay an alternative has been specified. Actual protection settings at the various voltage levels are included in Appendix B, revisions to settings are included in Appendix C.

The distribution system to be energised from the BESS 11.6 MVA (as work package two) consists of the connection from the Redhouse BESS site up to 33 kV Redhouse GSP board fed from 90 MVA Grid T1. The 132/33 kV transformer, 33 kV circuits to the local Redhouse transformer, Chapel and Birrel St Wynd will be energised along with the associated 33 /11 kV transformers.

The distribution system to be energised from the BESS to Glenrothes has been removed from the scope.

The transmission system to be energised from the BESS as work package four (WP4) will consist of the 132/33 kV grid transformer, Redhouse to Glenniston to Mossmorran 132 kV circuits and the Mossmorran SGT2 240 MVA, 275/132 kV transformer (and associated circuit connections).

Figures 6.1 and 6.2 detail the network included in the scope (also included as Figures A.1 and A.2).

THIS REPORT IS INTENDED TO COVER WORK PACKAGES TWO AND FOUR

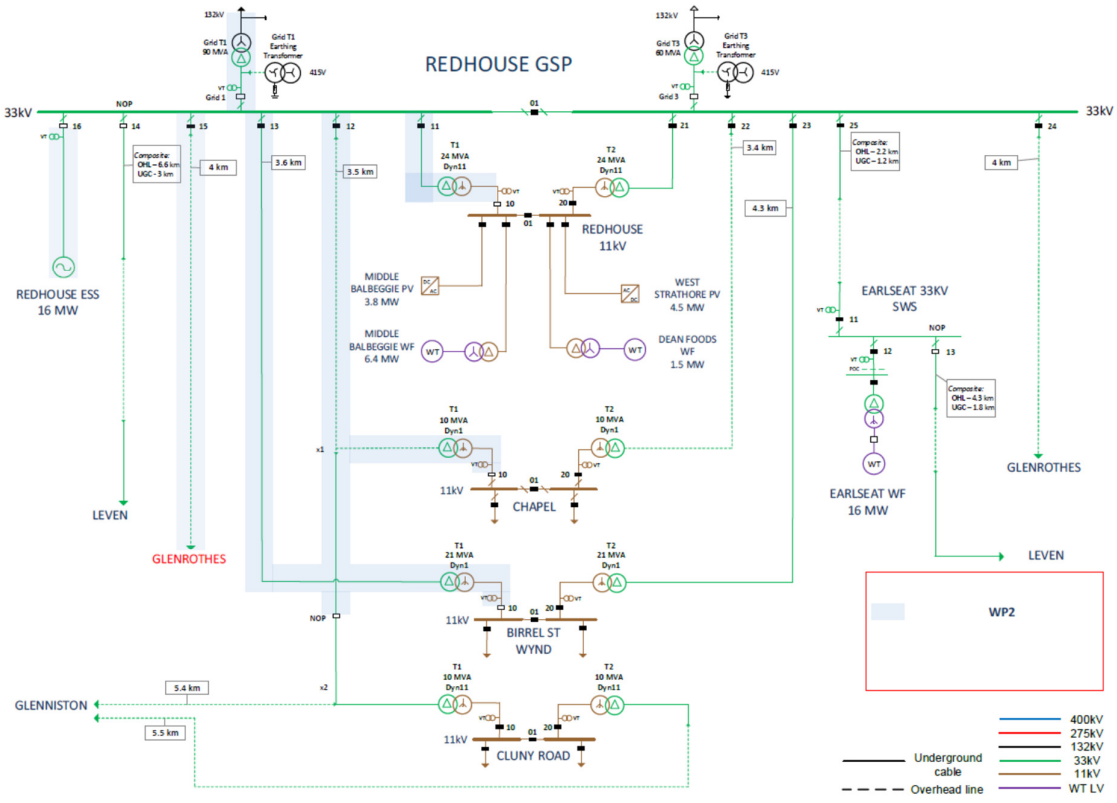


Figure 6.1: Redhouse Test Trial Network –WP2

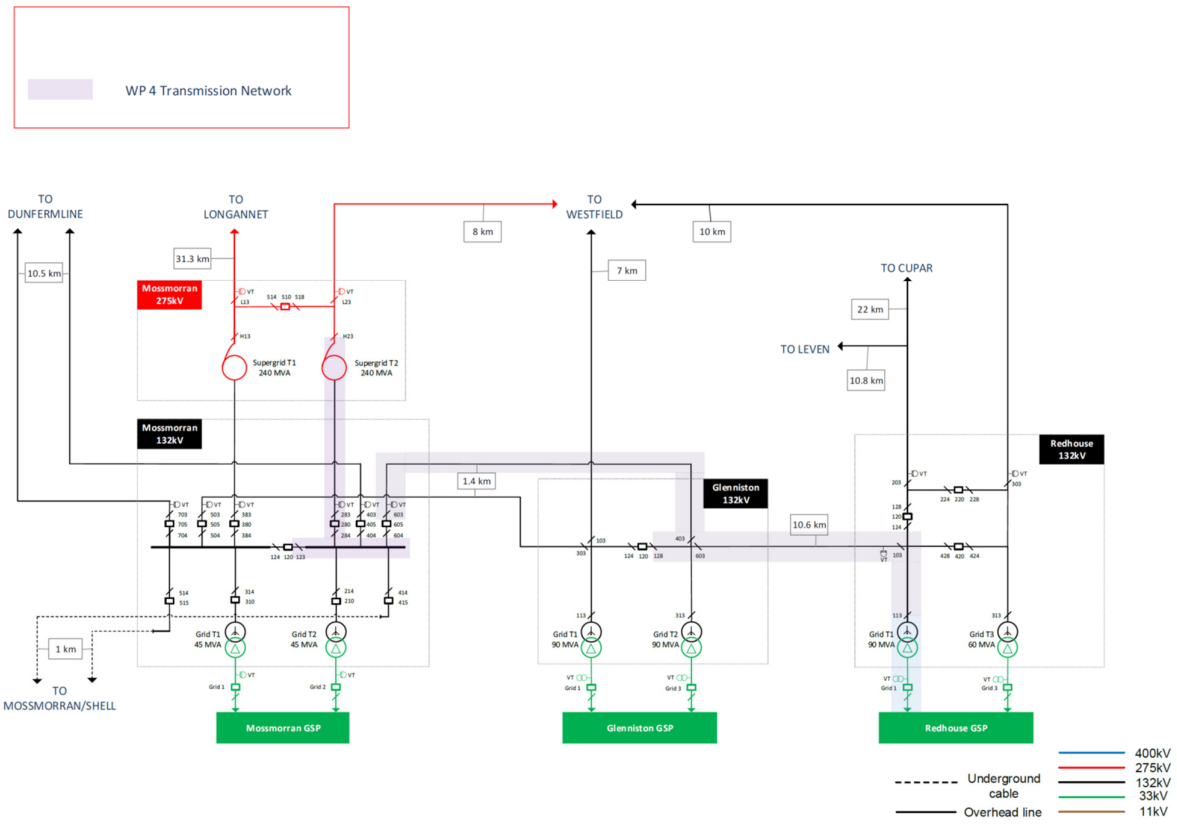


Figure 6.2: Redhouse Test Trial Network –WP4

Ideally it would be desirable to achieve discrimination throughout the 33 kV and 132 kV systems and provide suitable settings for the reduced black start fault levels. However, the practicality of being able to achieve this across all the locations with the reduced fault levels and the work involved should also be considered. Therefore, rather than changing every relay where possible relays settings may be left with the existing settings.

The settings provided here should be suitable for a black start on the system.

6.1 Redhouse Distribution Protection

This section looks at the 33 kV main protection and backup protection at Redhouse.

6.1.1 33 kV Main Protection

This section looks at the 33 kV main protection at Redhouse.

6.1.1.1 33kV Feeder Balanced Earth Fault Protection

Details on the existing 33 kV protection and settings are detailed in Appendix B. The Balanced earth fault is set with a 75V plug setting with 400/1 A CTs and 280 Ω resistor.

Policy PROT-01-009 states the following: -

- Overall fault setting shall be 10%-25% of fault current available for an earth fault at the 33/11 kV Tx LV terminals under minimum plant conditions (target setting 10%).
- The rated stability limit should be 16 x $I_{TX\ HV}$

Some assumptions have been made regarding the CT characteristics based on policy guidelines. The operating current of the relay would be for currents above approximately 125 Amps.

The balanced earth fault is suitable for the fault levels on BESS supply with or without diesel generator.

6.1.1.2 33kV Transformer Restricted Earth Fault

Details on the existing 33 kV protection and settings are detailed in Appendix B. The Redhouse 33 kV LV restricted earth fault is set with a 0.1 A setting with 1600/1 A CTs. The Redhouse LV restricted earth fault is provided by the Siemens Duobias relay with the following settings: -

- 0.1 A
- 1600 /1 A

Policy PROT-01-009 states the following for a 132/33 kV transformer:-

- Overall fault setting shall be 10%-60% of transformer full load (target setting 15%).
- The rated stability limit should be 16 x $I_{TX\ HV}$

For the 90 MVA rated transformer a target setting of 15 % would be 236A. The LV restricted earth fault protection's existing setting of 0.1 A equates to 160 A which is 20% of the maximum earth fault current from BESS and Diesel generators of 790 A.

The calculated fault at Redhouse 33 kV is 641 A from the BESS only, the pickup setting is 25 % of this magnitude of fault current and is sufficient to ensure satisfactory operation of the restricted earth fault protection.

6.1.1.3 33kV Transformer Standby Earth Fault

The transformer standby earth fault protection is as follows and will be discussed with the 33 kV backup earth fault protection section.

The SBEF protection on the grid transformer incomers has the following settings: -

- I> 160 A
- Curve Type LTI
- TM 0.225

and

- I> 212 A
- Curve Type LTI
- TM 0.25

6.1.1.4 33kV Transformer Directional Overcurrent

The transformer LV has directional overcurrent fitted as the supply is from the BESS system up onto the 132 kV system the directional overcurrent will be considered in the 132 kV backup overcurrent section.

6.1.1.5 33 kV Busbar Protection

Policy PROT-01-009 states the following: -

- 50-100% of busbar rating subject to the fault setting not exceeding 30% of fault current available for faults on the busbars under minimum plant conditions.
- Current setting does not exceed 50% of anticipated full load current rating of any single connected circuit.

Details of the actual bus-zone protection are unknown at present. Operation would depend on the effective primary operating current but this should not exceed 30% of fault current available in normal operation, in this case 472 A (90 MVA) The current setting should not exceed 50% of anticipated full load current rating of any single connected circuit. In this case not exceeding 210 A. Therefore, operation could not be guaranteed for three phase faults from the BESS supply.

6.1.2 33kV Backup Protection

This section looks at the backup 33 kV protection at Redhouse on the circuit feeders. The test trial does not include the connection to Leven or Glenrothes.

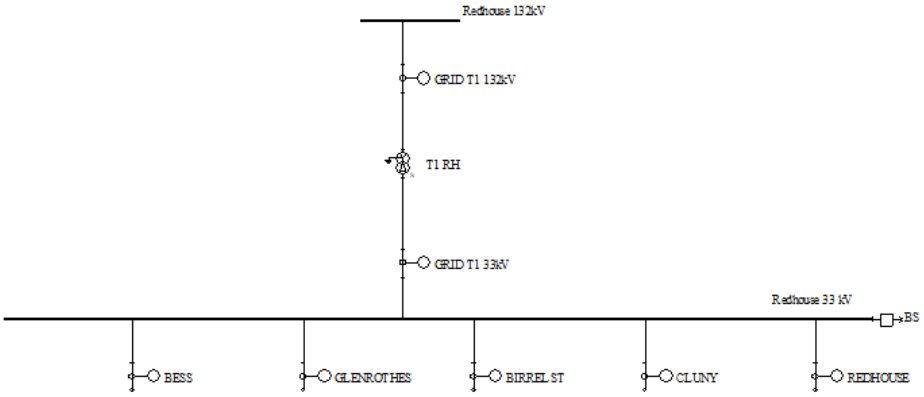


Figure 6.1.2.1 Existing 33 kV Protection Layout

6.1.2.1 33 kV Overcurrent Protection

The existing protection settings are detailed in Appendix B.

Existing Protection Discussion – Figure 6.1.2.2

Figure 6.1.2.2. details the existing overcurrent protection on the Redhouse 33 kV switchboard.

For the fault levels discussed in Section 5 a three-phase fault at Redhouse 33 kV is 213 A considering the BESS supply only (SC5) and 386 A considering BESS and diesel generator supply.

The existing protection on the 33 kV feeders all operate above 500 A. The P14N relays are all suitable for a second setting group specifically for black start.

Therefore, changes will be required to the backup overcurrent protection to ensure operation for three phase faults.

It should be noted that the BESS system connected is 11.6 MVA equivalent output of 203 A. The difference between the load and fault currents is small therefore it would be proposed in future to use voltage-controlled

overcurrent to differentiate between load and fault current. This would require a voltage input to be available for the 33 kV feeder protection.

For the trial the settings provided are to ensure that the protection operates for the fault condition to protect the system. A 5 MVA loadbank is proposed on the BESS system with no other system loading.

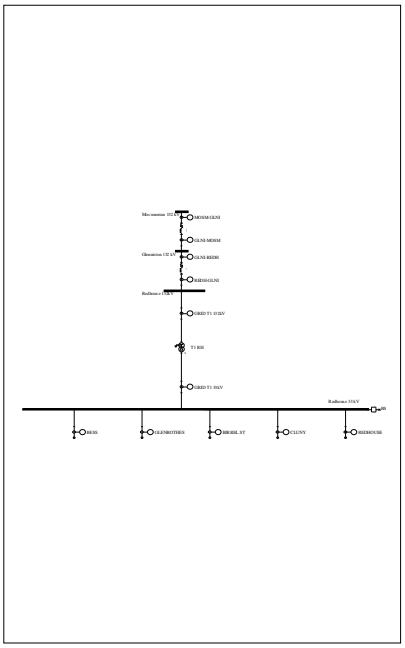
Revised Protection Discussion – Figure 6.1.2.3

The 33 kV feeder protection settings are set to ensure operation of the backup protection for faults. The BESS 33 kV feeder and 33 kV feeders to Cluny Road, Birrel St and Redhouse local are all set with the same pickup settings but grading is provided between the BESS 33 kV feeders and the 33 kV feeders from the 33 kV board. It would be determined by SPEN whether changes are made to all breakers or just the main BESS 33 kV feeder. The benefit of changing all breakers is that the BESS overcurrent protection would provide a backup to the 33 kV feeder overcurrent protection.

The integral protection on the BESS system is unknown but it is not required to grade with the backup overcurrent settings on the 33kV Redhouse switchboard feeders as for a fault condition in the trial it is important to operate the backup overcurrent protection to ensure that the system is tripped for fault conditions. Whether this is carried out by the 33 kV Redhouse protection or by the integral BESS protection scheme is irrelevant other than for fault finding.

For future trials it would be beneficial to have the BESS system protection settings and to determine some grading between the devices for fault location and isolation of only the faulted part of the system. With the addition of load onto the system it would also require voltage-controlled protection to allow for the full load from the BESS to differentiate between a healthy load condition and an unhealthy fault condition.

Relays Name/Type	CT Ratio (A)	Description	Settings
BIRREL ST OC Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.25 (500A) IEC S Inv - I>1 TMS 0.4 I>3 Current Set x In 8 (3200A)
CLUNY OC Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.25 (500A) IEC S Inv - I>1 TMS 0.4 I>3 Current Set x In 6 (2400A)
REDHOUSE OC Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.25 (500A) IEC S Inv - I>1 TMS 0.3 I>3 Current Set x In 8 (3200A)
REDHOUSE BS OC Electronic	1600 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (1280A) IEC S Inv - I>1 TMS 0.275
BESS OC Electronic	800 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.5 (400A) IEC S Inv - I>1 TMS 0.3



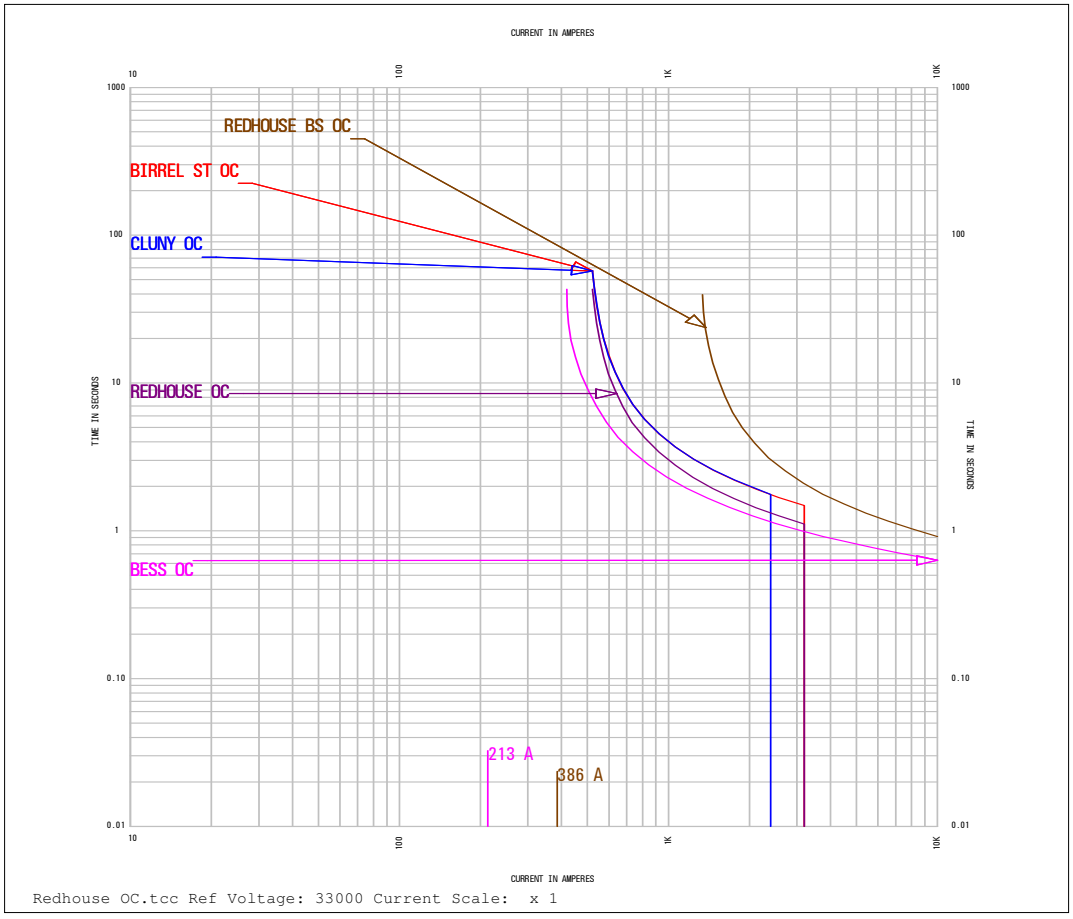
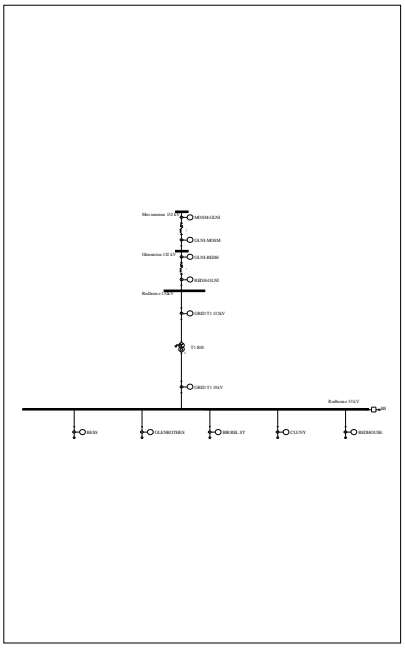


Figure 6.1.2.2 Existing 33 kV Overcurrent Protection

Relays Name/Type	CT Ratio (A)	Description	Settings
REDHOUSE BS OC Electronic	1600 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (1280A) IEC S Inv - I>1 TMS 0.275
BESS OC REV Electronic	800 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.13 (104A) Def Time - I>1 TD 0.3 (sec)
REDHOUSE OC REV Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.25 (100A) Def Time - I>1 TD 0.1 (sec) I>3 Current Set x In 8 (3200A)
CLUNY OC REV Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.25 (100A) Def Time - I>1 TD 0.1 (sec) I>3 Current Set x In 6 (2400A)
BIRREL ST OC REV Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.25 (100A) Def Time - I>1 TD 0.1 (sec) I>3 Current Set x In 8 (3200A)



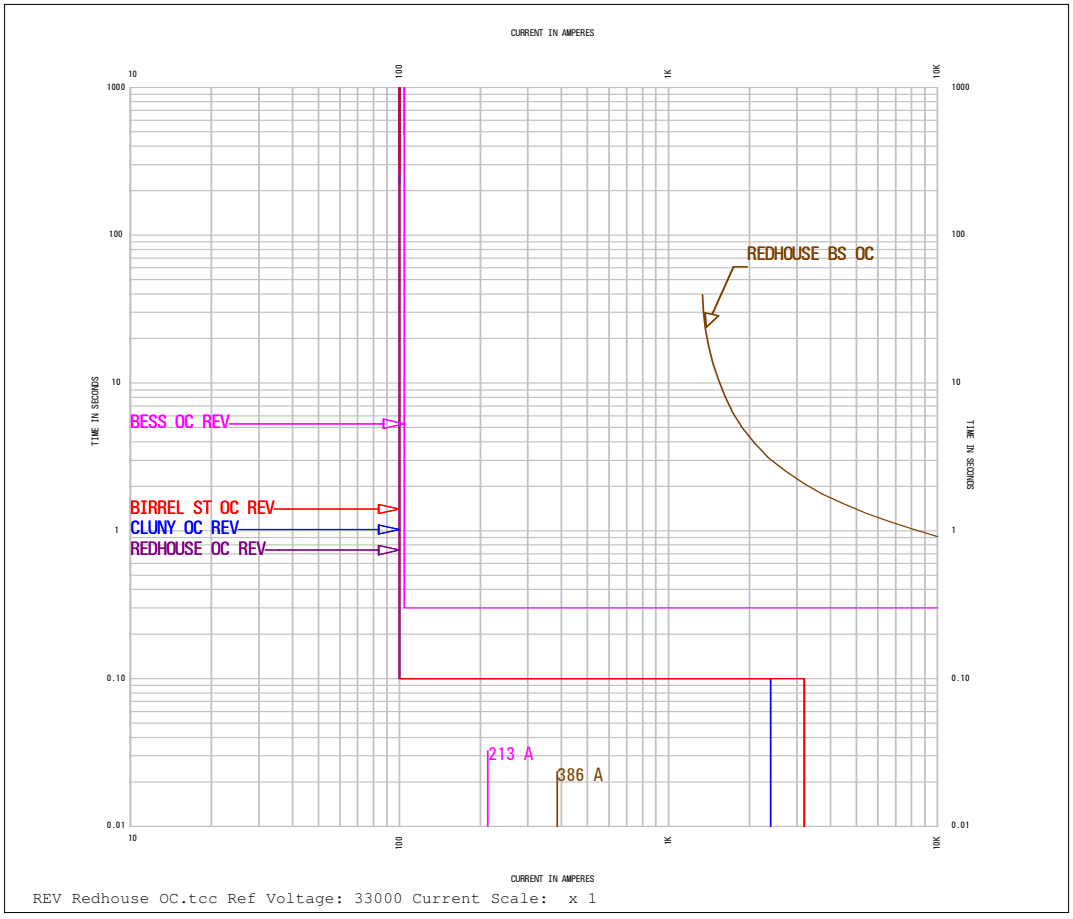


Figure 6.1.2.3 Revised 33 kV Overcurrent Protection

6.1.2.2 33 kV Earth fault Protection

Figure 6.1.2.4. details the existing earth fault protection on the Redhouse 33 kV switchboard.

For the fault levels discussed in Section 5 an earth fault at Redhouse 33 kV is 641 A considering the BESS supply only (SC5) and 790 A considering BESS and diesel generator supply.

The existing protection on the feeders all operate above 80 A. The P14N relays are all suitable for a second setting group specifically for black start.

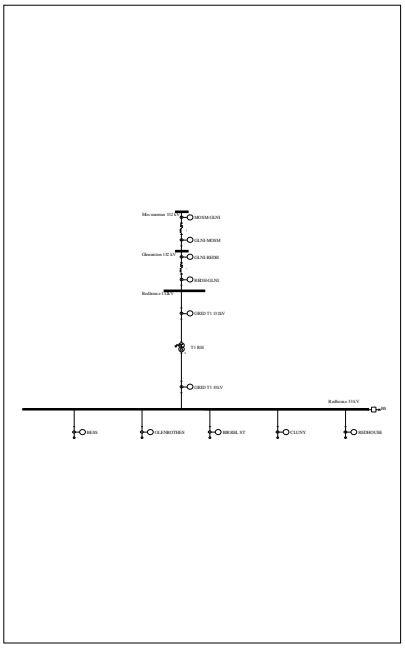
The existing earth fault protection would operate for the fault conditions here.

The BESS EF protection would see the contribution coming from the BESS system to an earth fault. The BESS EF protection would see 369 A considering the BESS supply only and 439 A considering the BESS and diesel generator supply. Operating at 1.54 s and 1.33 s respectively.

The 33 kV feeder protection operates 0.329s.

For a 33 kV fault on the grid transformer incomer the fault would be cleared by the BESS feeder protection which would remove the source.

Relays Name/Type	CT Ratio (A)	Description	Settings
BIRREL ST EF Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.2 (80A) IEC S Inv - I>1 TMS 0.1
CLUNY EF Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.2 (80A) IEC S Inv - I>1 TMS 0.1
REDHOUSE EF Electronic	400 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.2 (80A) IEC S Inv - I>1 TMS 0.1
BESS EF Electronic	800 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.15 (120A) IEC S Inv - I>1 TMS 0.25
REDHOUSE BS EF Electronic	1600 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.08 (128A) IEC S Inv - I>1 TMS 0.35
GRID T1 33kV SBEF1 Electronic	1600 / 1	GEC KCGG 1A	I > 0.1 (160A) Long Time Inverse 0.225
GRID T1 33kV SBEF2 Electronic	1600 / 1	GEC KCGG 1A	I > 0.1325 (212A) Long Time Inverse 0.25



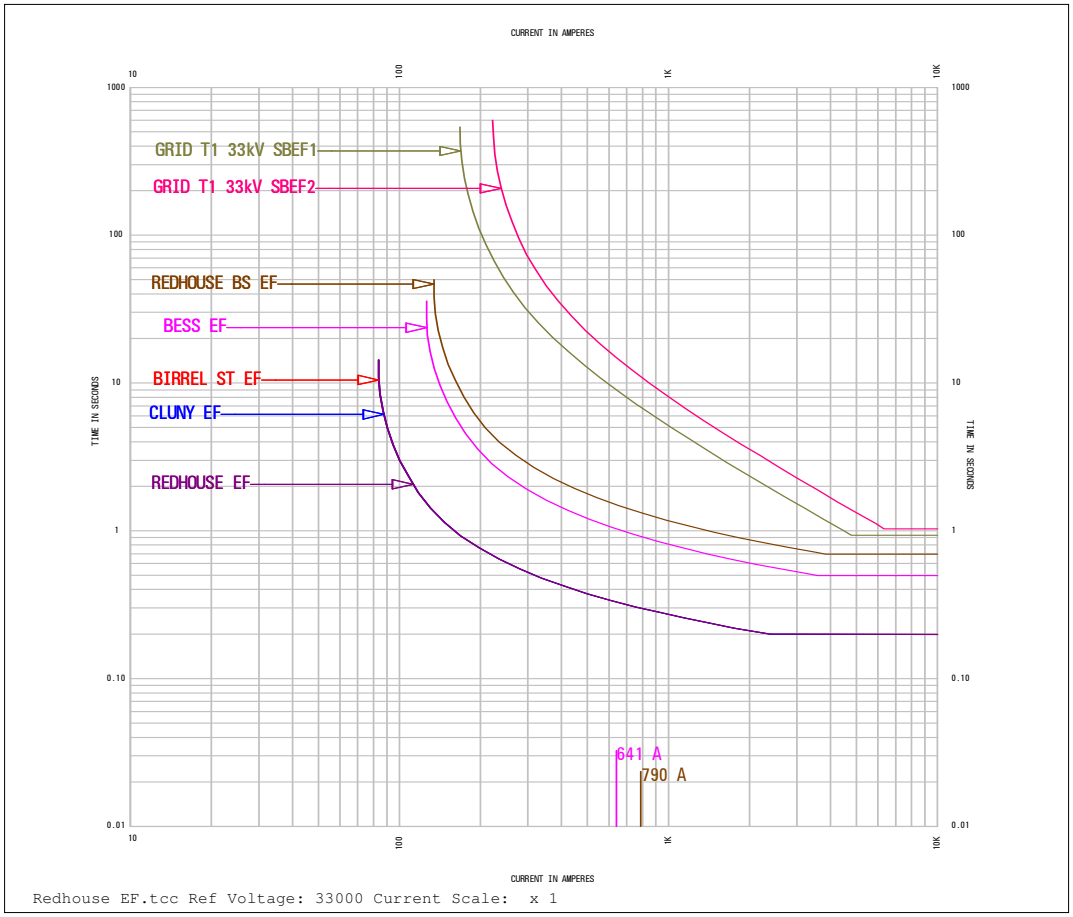


Figure 6.1.2.4 Existing 33 kV Earth Fault Protection

6.2 Redhouse Transmission Protection

6.2.1 132 kV Main Protection

6.2.1.1 132 kV Unit Feeder Protection

Policy PROT-01-009 states the following: -

- 10-30% of In (based on CT 1A secondary)
- The minimum credible in zone fault current shall produce a multiple of protection fault setting of at least 1.5
- The protection shall operate for all fault types within the protected zone with a Rf up to 100 Ω

In order to meet the policy, the feeder unit protection should clear faults greater than 762 A @ 132 kV. The unit protection here is three ended and includes Glenniston and Mossmorran.

The main protection is provided by P545 relays. These relays have a second setting group.

The settings applied are as follows: -

- Is1 pickup 0.2 x In
- Is2 = 2.3 x In
- K1 = 30%
- K2 = 100%
- DT
- 0s

The CTs at Redhouse and Glenniston are 500/1.

The three-phase fault level at the Mossmorran end of the feeder is 53 A from BESS and 94 A from BESS and diesel generation. The earth fault level at the Mossmorran end of the feeder is 160 A from BESS and 231 A from BESS and diesel generation.

The P545 relays are fed by 500/1A CTs. The pickup of the device is therefore 100 A.

Policy states that operation should be obtained for a 100 Ω fault. For the magnitude of fault levels here and the fault impedance the device would not operate for three phase faults with the existing settings. The minimum setting pickup for the device is 0.2 x In so there is no scope to lower the protection.

6.2.1.2 Connections Standby Protection

The Redhouse 132 kV copperwork is not protected by mesh corner protection. The backup protection P14N relay provides protection when the Glenniston feeder is in service and the P14N (using the relay's instantaneous overcurrent function) provides protection when the Glenniston feeder is not in service. The site settings for the P14N when the Glenniston feeder is out of service are as follows: -

- 500/1
- Standby protection 6000 A

The P14N backup protection would be in service as the Glenniston feeder is in service for the test condition relies on the backup protection detailed in section 6.2.2 below.

6.2.1.3 132 kV / 33 kV Transformer Differential Redhouse

Policy PROT-01-009 states the following: -

- Biased Differential Characteristic
- Minimum operating current of 15% of transformer HV winding rating.

The Redhouse T1 90MVA grid transformer protection is provided by a Siemens Duobias biased differential relay with the following settings.

- 500/1 A
- ICT W1 = 1.5, W2 1.26.
- Initial Setting 30%
- 1st Bias Slope 30%
- 1st Bias Slope Limit 8 x In
- 2nd Bias Slope Curve assumed
- Highset 10 x In

With a 1st bias slope of 30% and an initial setting of 30% increased biasing will start to occur for restraint current in excess of 1 x In. Therefore, the initial setting of 30% would be valid up to the 90 MVA rating of the transformer.

During supply from the BESS the maximum load on the transformer will be significantly less than this and therefore the differential protection will operate for faults in excess of 100 A at 132 kV and would **NOT** be sensitive enough to detect three phase faults on the 132 kV side of the transformer.

A 33 kV three phase fault on the transformer would only be detected if the BESS and diesel generators are in operation.

The existing initial setting could be reduced to its minimum setting which would allow the device to be more sensitive to in-zone three phase faults.

Changes to settings are provided in Appendix C

6.2.1.4 132 kV Transformer HV Restricted Earth Fault Protection (HV REF)

The Redhouse HV restricted earth fault is provided by the Siemens Duobias relay with the following settings: -

- 0.06 A
- 500/1 A

Policy PROT-01-009 states the following: -

- 10-60% of transformer HV winding rating (target 15%)

Operating at 0.06 A on a 500/1 A CT is equivalent to 30 A therefore approximately 8% of rating (FLC = 394 A). This is equal to 19% of the calculated earth fault level at Redhouse 132 kV (BESS only) and 13% of the calculated earth fault level including the diesel generation. The setting is below policy.

The transformer HV restricted earth fault protection only covers the transformer winding; it will not operate for faults on the 132 kV feeder to Glenniston or faults elsewhere on the 132 kV system.

6.2.1.5 132 kV Busbar Protection

Policy PROT-01-009 is to normally set the protection between 50%-100% of the busbar rating subject to the fault setting not exceeding 30% of fault current available for faults on the busbars under minimum plant conditions.

For a 2000 A busbar the fault current here is equivalent to 3% of the busbar rating and the busbar protection will not operate for faults.

Interlocked overcurrent protection initiated from the 132 kV busbar protection at Mossmorran is provided to cover the short zone fault at Mossmorran and intertrip to the remote ends of the lines as the circuit CTs are only located on the line side of the circuit breaker. This is illustrated on the 132 kV backup overcurrent figure.

6.2.2 132 kV Backup Protection

This section looks at the backup 132 kV protection from Redhouse to Mossmorran.

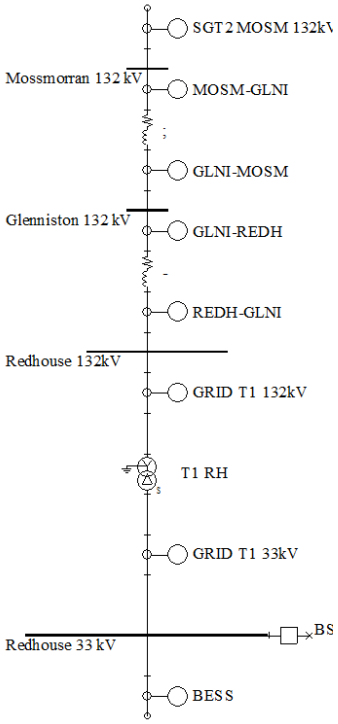


Figure 6.2.2.1 Existing 132 kV Protection Layout

6.2.2.1 132 kV Overcurrent Protection

The existing protection settings are detailed in Appendix B. Figure 6.2.2.2 details the 132 kV overcurrent backup protection.

Existing Protection Discussion- Figure 6.2.2.2

For the fault levels discussed in Section 5 a three-phase fault at Redhouse 33 kV is 213 A considering the BESS supply only (SC5) and 386 A considering BESS and diesel generator supply.

For the fault levels discussed in Section 5 a three-phase fault at Redhouse 132 kV is 53 A considering the BESS supply only (SC5) and 94 A considering BESS and diesel generator supply.

Directional overcurrent protection exists on the Redhouse Grid transformer 33 kV which could operate for faults fed from the BESS system. The 132 kV feeder backup overcurrent protection from Redhouse to Glenniston and Glenniston to Mossmorran are all set with similar settings therefore there is no discrimination between the backup overcurrent devices for faults.

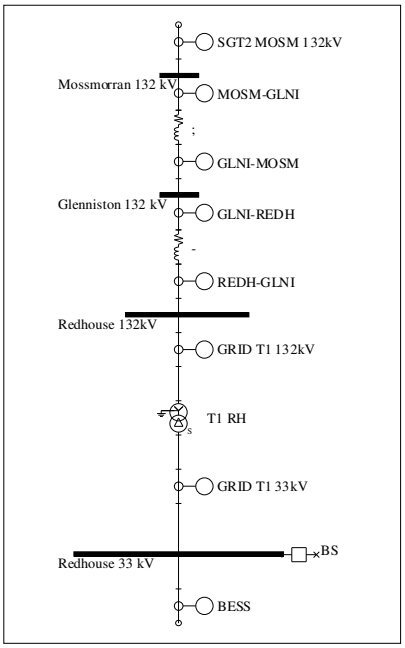
At the system fault levels here none of the backup overcurrent protection would operate for 132 kV faults.

Revised Protection Discussion- Figure 6.2.2.3

For the trial it is suggested that the directional overcurrent protection on the grid transformer is made sensitive to operate for faults on the 132 kV system. Further backup protection is provided by the 132 kV overcurrent protection..

The settings selected for the directional overcurrent protection are graded with the BESS overcurrent revised settings.

Relays Name/Type	CT Ratio (A)	Description	Settings
GRID T1 33kV DOC Electronic	600 / 1	GEC KCGG 1A	I > 0.88 (528A) Standard Inv 0.1
GRID T1 132kV OC Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.1 (550A) IEC S Inv - I>1 TMS 0.35
REDH-GLNI OC Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.62 (810A) IEC S Inv - I>1 TMS 0.4
GLNI-REDH OC Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.62 (810A) IEC S Inv - I>1 TMS 0.4
GLNI-MOSM OC Electro-Mechanical	500 / 1	REYROLLE PCS TJM10,11,12	Tap (0.5-2.0A) 1.5 (750A) Time Dials 0.4
MOSM-GLNI OC Electro-Mechanical	500 / 1	GEC CDG SI	PS 1.5 (750A) TMS 0.4
SGT2 MOSM 132kV Electronic	600 / 1	GEC KCGG 1A	I > 2.56 (1536A) Standard Inv 0.35
BESS OC Electronic	800 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.5 (400A) IEC S Inv - I>1 TMS 0.3
MOSM-GLNI ILOC Electronic	600 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.4 (240A) Def Time - I>1 TD 0.4 (sec)



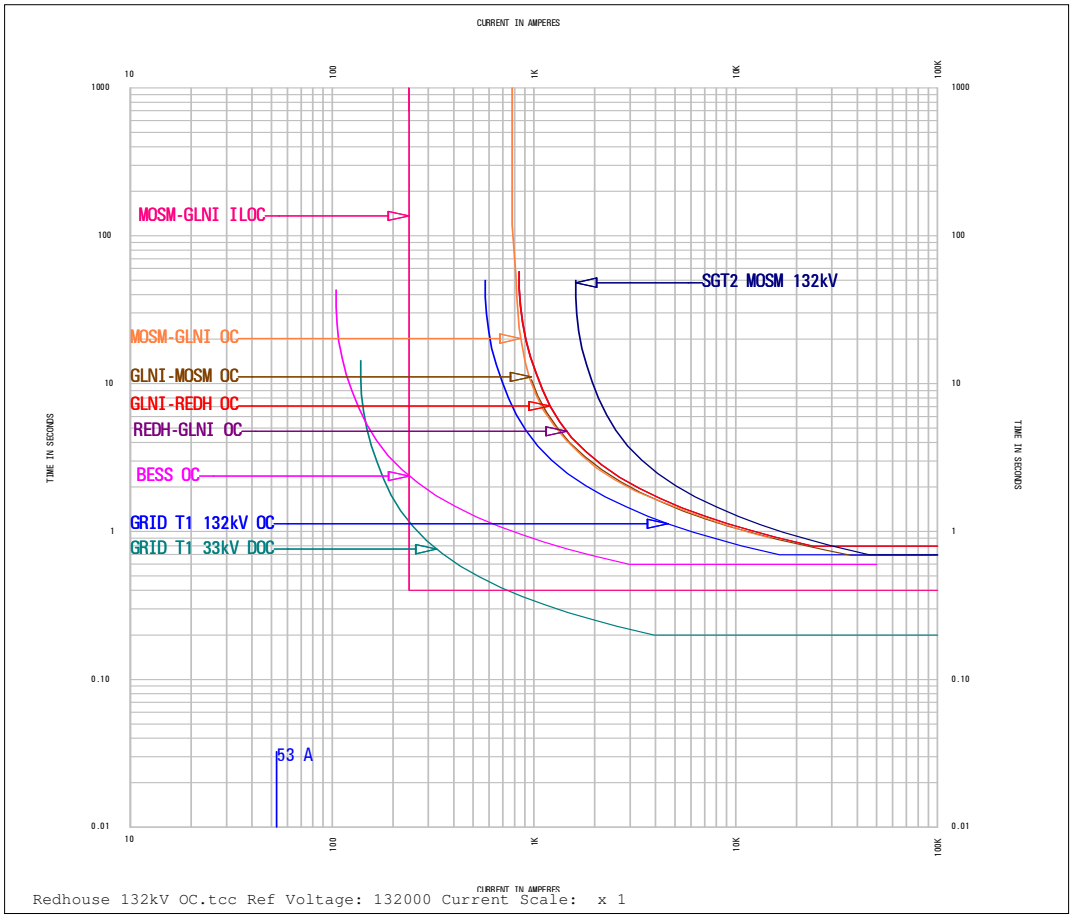
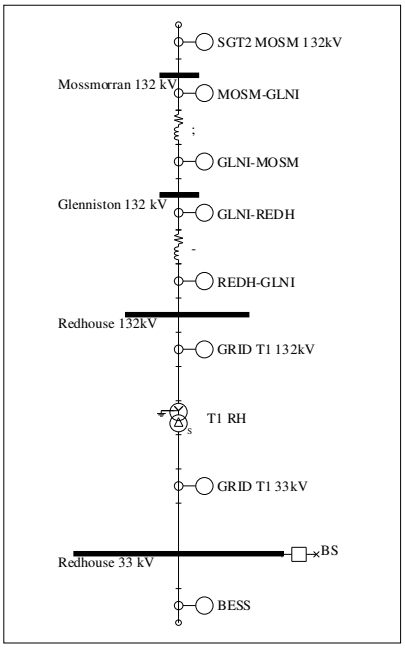


Figure 6.2.2.2 Existing 132 kV Overcurrent Protection

Relays

Name/Type	CT Ratio (A)	Description	Settings
GRID T1 132kV OCREV Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.08 (40A) Def Time - I>1 TD 0.1 (sec)
REDH-GLNI OC Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.62 (810A) IEC S Inv - I>1 TMS 0.4
GLNI-REDH OC Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 1.62 (810A) IEC S Inv - I>1 TMS 0.4
GLNI-MOSM OC Electro-Mechanical	500 / 1	REYROLLE PCS TJM10,11,12	Tap (0.5-2.0A) 1.5 (750A) Time Dials 0.4
MOSM-GLNI OC Electro-Mechanical	500 / 1	GEC CDG SI	PS 1.5 (750A) TMS 0.4
SGT2 MOSM 132kV Electronic	600 / 1	GEC KCGG 1A	I > 2.56 (1536A) Standard Inv 0.35
GRID T1 33kV DOC REV Electronic	600 / 1	GEC KCGG 1A	I > 0.17 (102A) t > 0.1 (sec)
BESS OC REV Electronic	800 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.13 (104A) Def Time - I>1 TD 0.3 (sec)
MOSM-GLNI ILOC Electronic	600 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.4 (240A) Def Time - I>1 TD 0.4 (sec)



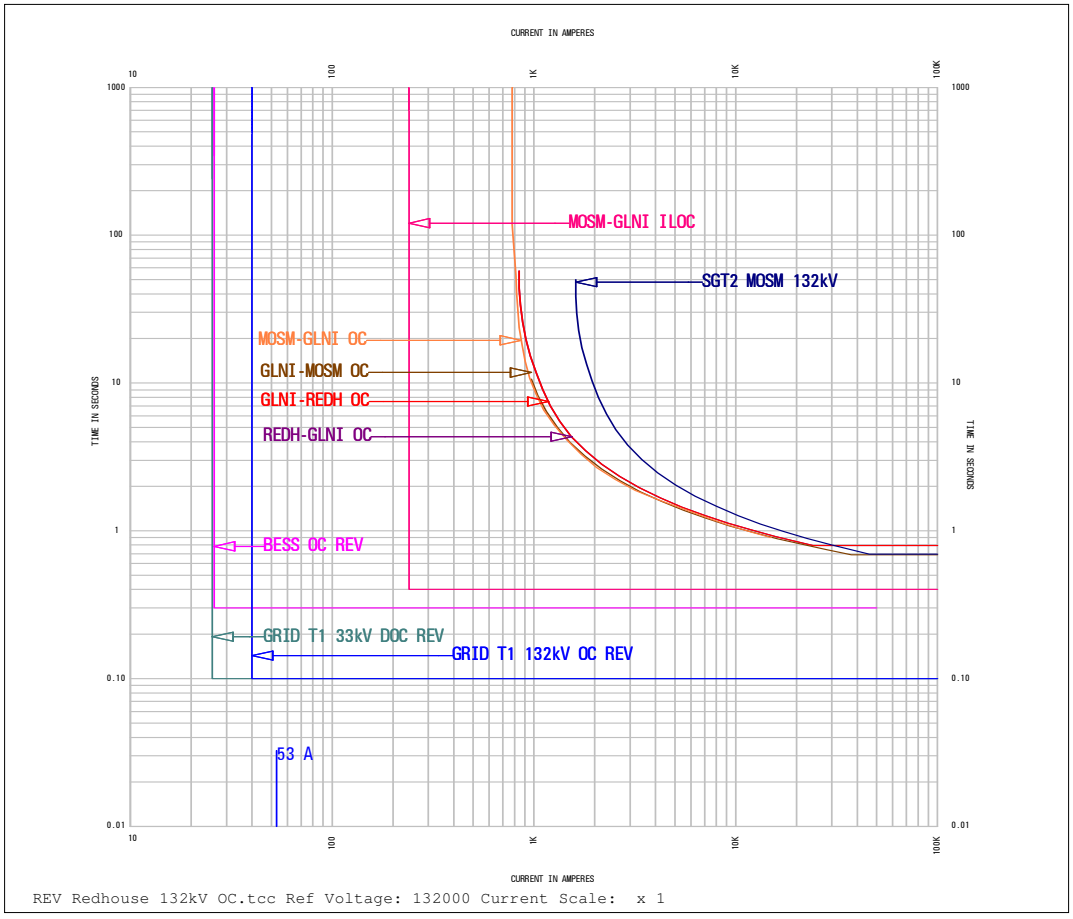


Figure 6.2.2.3 Revised 132 kV Overcurrent Protection

6.2.2.2 132 kV Earth Fault Protection

Figure 6.2.2.4. details the existing 132 kV earth fault protection.

Existing Protection Discussion- Figure 6.2.2.4

For the fault levels discussed in Section 5 an earth fault at Redhouse 132 kV is 160 A considering the BESS supply only (SC5) and 232 A considering BESS and diesel generator supply.

The existing 132 kV earth fault protection would not be guaranteed to operate for the fault conditions here. The 132 kV feeder earth fault protection is only fitted on the Redhouse to Glenniston and Glenniston to Redhouse feeder, there is no backup earth fault protection on the section from Glenniston to Mossmorran nor vice versa. The 132 kV backup earth fault protection on the feeders operates for faults above 400 A therefore would not pickup for the fault levels here. The P14N relays are all suitable for a second setting group specifically for black start.

The Mossmorran supergrid transformer earth fault protection at 132 kV is set to operate for faults above 120 A therefore could possibly operate at the fault level of 160 A which is 1.3 times the pickup. However, the operation time is approximately 24 s.

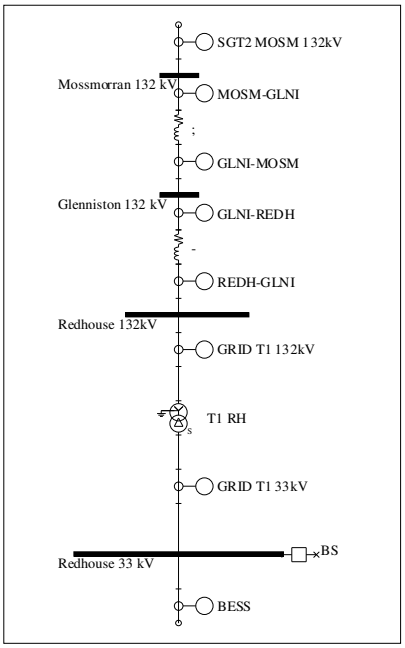
A 132 kV earth fault would appear on the 33 kV system in 2 phases. The referred directional overcurrent and BESS backup overcurrent protection have been plotted on Figure 6.2.2.4. At present neither would operate for a 132 kV earth fault. However, both associated relays are able to be set with a second group of settings.

Revisions are required to protect for 132 kV earth faults.

Revised Protection Discussion- Figure 6.2.2.5

Changes to the 33 kV directional overcurrent protection are provided to ensure the protection picks up for 132 kV earth faults. As backup it is suggested that the grid transformer at Redhouse has earth fault protection set to protect the 132 kV system to Mossmorran. This is provided by the 132 kV backup overcurrent protection with reduced settings.

Relays Name/Type	CT Ratio (A)	Description	Settings
REDH-GLNI EF Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (400A) IEC S Inv - I>1 TMS 0.6
GLNI-REDH EF Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (400A) IEC S Inv - I>1 TMS 0.6
SGT2 MOSM 132kV EF Electronic	600 / 1	GEC KCGG 1A	I > 0.2 (120A) Standard Inv 1
GRID T1 33kV DOC ref Electronic	1039 / 1	GEC KCGG 1A	I > 0.88 (914.32A) Standard Inv 0.1
BESS OC ref Electronic	1386 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.5 (693A) IEC S Inv - I>1 TMS 0.3



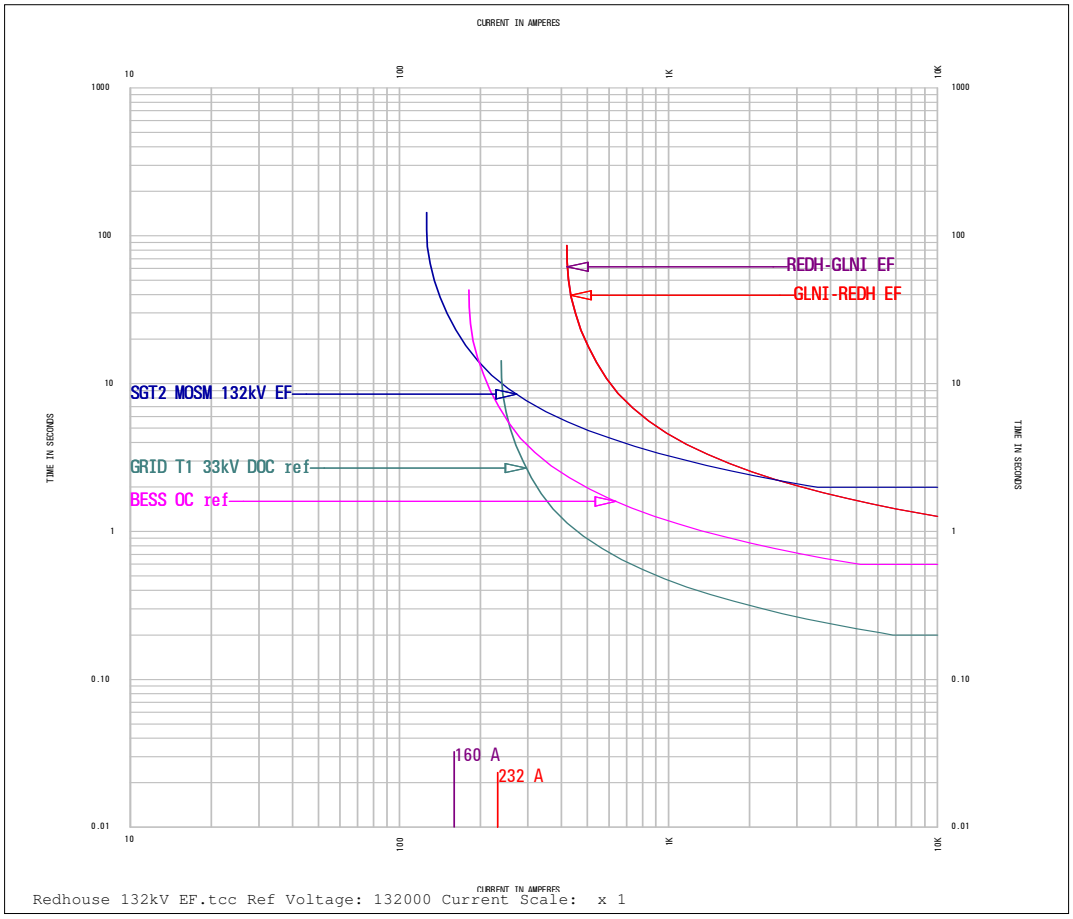
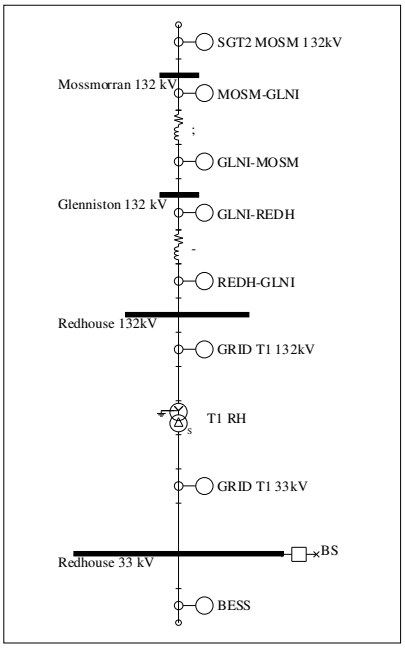


Figure 6.2.2.4 Existing 132 kV Earth Fault Protection

Relays Name/Type	CT Ratio (A)	Description	Settings
REDH-GLNI EF Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (400A) IEC S Inv - I>1 TMS 0.6
GLNI-REDH EF Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.8 (400A) IEC S Inv - I>1 TMS 0.6
SGT2 MOSM 132kV EF Electronic	600 / 1	GEC KCGG 1A	I > 0.2 (120A) Standard Inv 1
BESS OC REV ref Electronic	1386 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.13 (180.18A) Def Time - I>1 TD 0.3 (sec)
GRID T1 33kV DOC REV ref Electronic	1039 / 1	GEC KCGG 1A	I > 0.17 (176.63A) t > 0.1 (sec)
GRID T1 132kV OC REV Electronic	500 / 1	AREVA1 MiCOM P14N	I>1 Current Set x In 0.08 (40A) Def Time - I>1 TD 0.1 (sec)



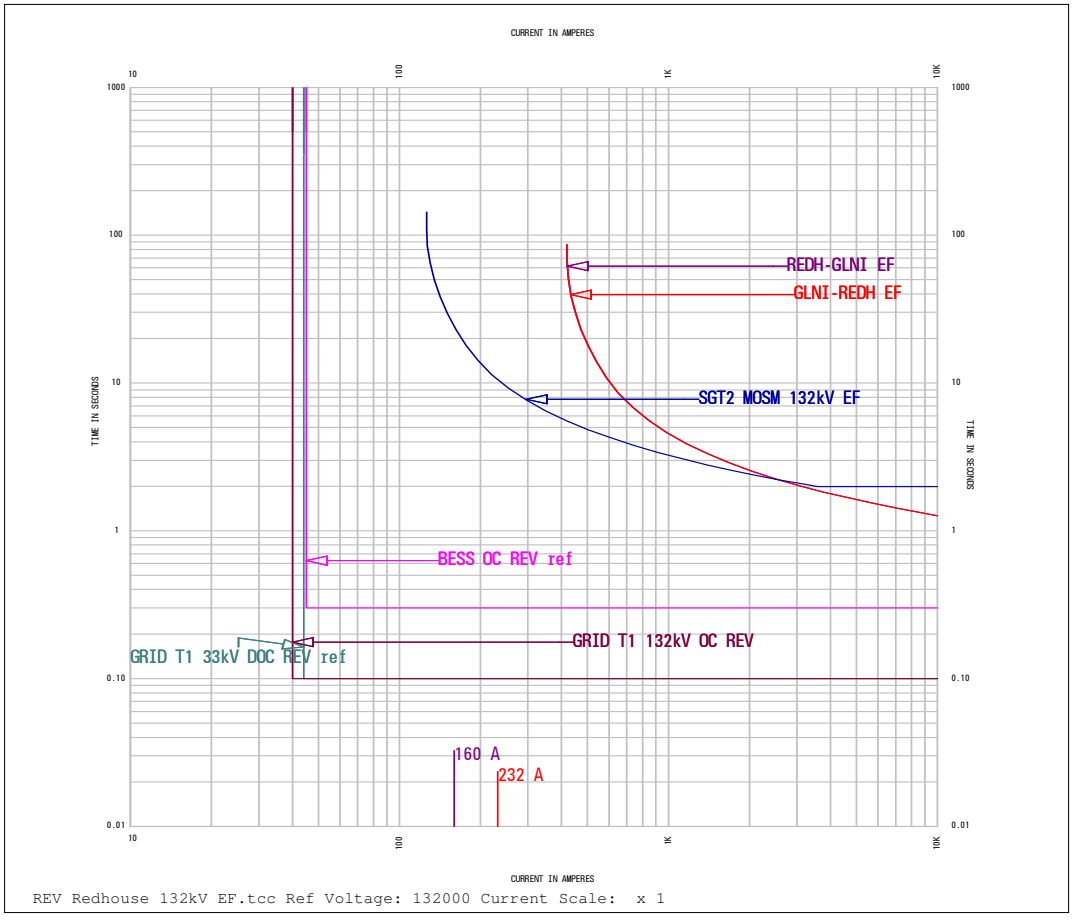


Figure 6.2.2.5 Revised 132 kV Earth Fault Protection

6.3 Protection Summary, Potential Issues and Mitigation Options

Potential issues affecting the protection of the distribution network are detailed below. Each potential issue is accompanied by a description of any mitigation option(s) identified.

For the black start scenario, the BESS is to supply the system. The integral protection on the BESS system is unknown at present. For the trial it should be ensured that protection at Redhouse 33 kV and the proposed 132 kV protection operates to ensure that the system is protected. Protection limitations are detailed in the sections below.

6.3.1 33 kV System Limitations

The 33 kV balanced earth fault protection and backup earth fault protection would operate for the fault levels here. The 33 kV transformer restricted earth fault and standby earth fault protection would operate for the reduced fault levels here.

Changes are required to the 33 kV feeder overcurrent protection and transformer differential protection and directional overcurrent protection to ensure operation for the reduced fault levels.

Settings have been proposed to ensure operation of the 33 kV protection at reduced fault levels, ensuring that the fault levels are above 2x device pickup. The trial is not being carried out while the system is loaded therefore the reduction of the selected settings to approximately 100 A should not affect operation of the system.

In future considering system loading voltage-controlled overcurrent would be required as the fault current and supply current from the BESS are similar and the protection would need to differentiate between load current and fault current.

6.3.2 132 kV System Limitations

The 132 kV line protection would not operate for black start fault levels and the backup protection would also not operate. The only 132 kV protection to operate would be the HV restricted earth fault on the 132/33 kV transformer for earth faults on the transformer winding.

The 132 kV line differential protection is set at its minimum pickup therefore the settings cannot be adjusted to operate for the reduced fault levels determined.

The minimum pickup for the 132 kV backup protection settings would be 40 A (it is not desirable to reduce the voltage-controlled pickup below this level). The fault levels from the BESS supply alone are only 1.3 x the device possible pickup.

Therefore, there is a limitation to the operation of the 132 kV backup protection due to the CTs and settings available on the relays.

7 Conclusions & Recommendations

The conclusions and recommendations of this study looking at the protection associated with performing a black start from distributed energy resources (DER), specifically from Redhouse Battery Energy Storage System (BESS), are detailed below:

7.1 Conclusions

This report documents the protection limitations and changes required for the 33 kV and 132 kV protection systems for the black start trial condition fed via a Redhouse Battery Energy Storage System (BESS) due to the reduction in fault levels at these voltage levels.

The extent of the changes were determined by the level of grading that is required and the fault clearance times required to protect equipment. For the trial, grading between devices on the 33 kV DNO system and the 33 kV BESS system were not considered. As the trial system will not be loaded the protection settings provided were set to ensure operation of the devices for the reduced fault levels.

Settings for the trial are provided in Appendix C.

The main limitations in going forward with the BESS system supplying for a black start would be the differentiation of load current and fault current. This can be done on the 33 kV system using voltage-controlled overcurrent but requires a voltage signal to determine a fault condition. This function is available on the 33 kV feeders but not on the transformer 33 kV protection device.

The main limitation with the 132 kV system is the reduced fault level is not sufficient with the BESS system only to operate the line differential protection or for voltage-controlled overcurrent protection as the pickup for the voltage control can only be reduced to the pickup setting of the relay, in this case 40 A for a 500/1 A CT. The 132 kV system is limited by the CT ratio and settings available on the devices. Therefore 132 kV phase faults may not be detected.

In summary the existing protection at 33 kV and 132 kV is limited and not adequately protecting the system for faults during black start. Consideration should be given to UV and OV protection on the BESS (i.e. its G99 protection) this could be used to detect additional asymmetric faults. Consideration should also be given to setting the negative sequence NPS overvoltage (ANSI 47) protection on the BESS G99 protection. The NPS voltage distortion is higher the smaller the NPS current is so this would offset some uncertainty in the way the NPS current has been modelled allowing detection of more fault conditions.

8 References

1 PROT-01-006 Issue 6 - 33kV Protection and Control Application Policy

2 PROT-01-007 Issue 6 - 132kV Protection and Control Application Policy

3 PROT-01-009 Issue 4 - Protection and Control Setting Policy

4 PROT-01-012 Issue 2 - 11kV Protection and Control Application Policy

5 PROT-01-014 Issue 2 - 11kV and 6.6kV Protection and Control Settings Policy

6 PROT-03-020 Issue 10 - Technical Specification for 33kV Protection and Control Equipment

7 PROT-01-008 Issue 6 -400kV and 275kV Protection and Control Application Policy

8 The Distribution Code of Licensed Distribution Network Operators of Great Britain, Issue 39, 23rd May 2019

9 The Grid Code Issue 5 Revision 34, 23rd May 2019

10 ENA Engineering Recommendation G59, Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed Distribution Network Operators, Issue 3 Amendment 6, 16th June 2019

11 ENA Engineering Recommendation G99, Requirements for the Connection of Generation Equipment in Parallel with Public Distribution Networks on or After 27 April 2019, Issue 1 Amendment 4, 16th June 2019

12 The Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002

13 National Grid ESO, Electricity Ten Year Statement (ETYS), November 2018

14 SP Distribution Long Term Development Statement (LTDS), November 2018

15 Long Term Development Statement (LTDS) for Scottish Hydro Electric Power Distribution Plc's Electricity Distribution System, November 2018

16 PROT-21-065 Issue 3 Redhouse -Glenniston-Mossmorran Data Sheet.pdf

17 Protection Settings for 33 kV Redhouse – D Restart Project.doc Email 14/4/21

18 D Restart Chapelcross & Redhouse Protection Info Email 14/5/21

19 Protection Setting for Transmission - Email from A.Mackay 11/5/21

20 Protection Setting for Transmission - Email from R.Aspin 17/6/21 12:52

21 Protection Setting for Transmission - Email from R.Aspin 29/6/21

22 10048782-R-PW-01 Issue B Redhouse Live Trial Fault Levels

APPENDIX A

Network Diagrams & Tables

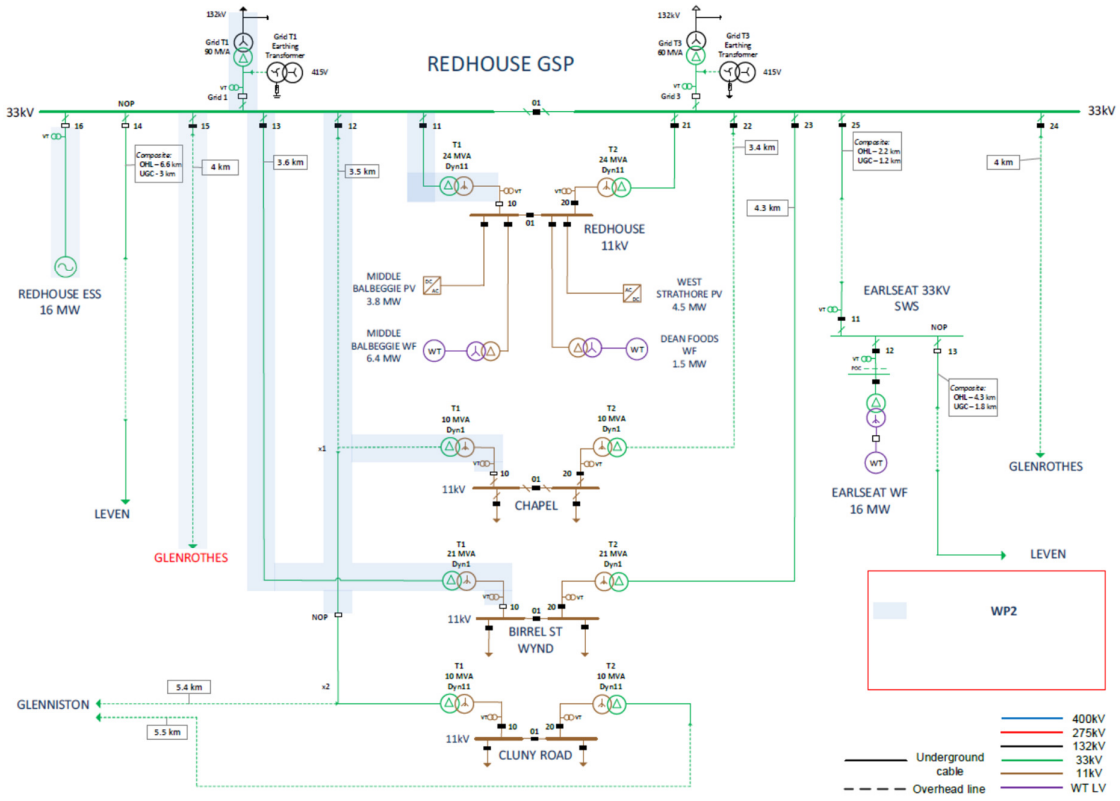


Figure A.1: Redhouse Distribution WP2 Test Diagram

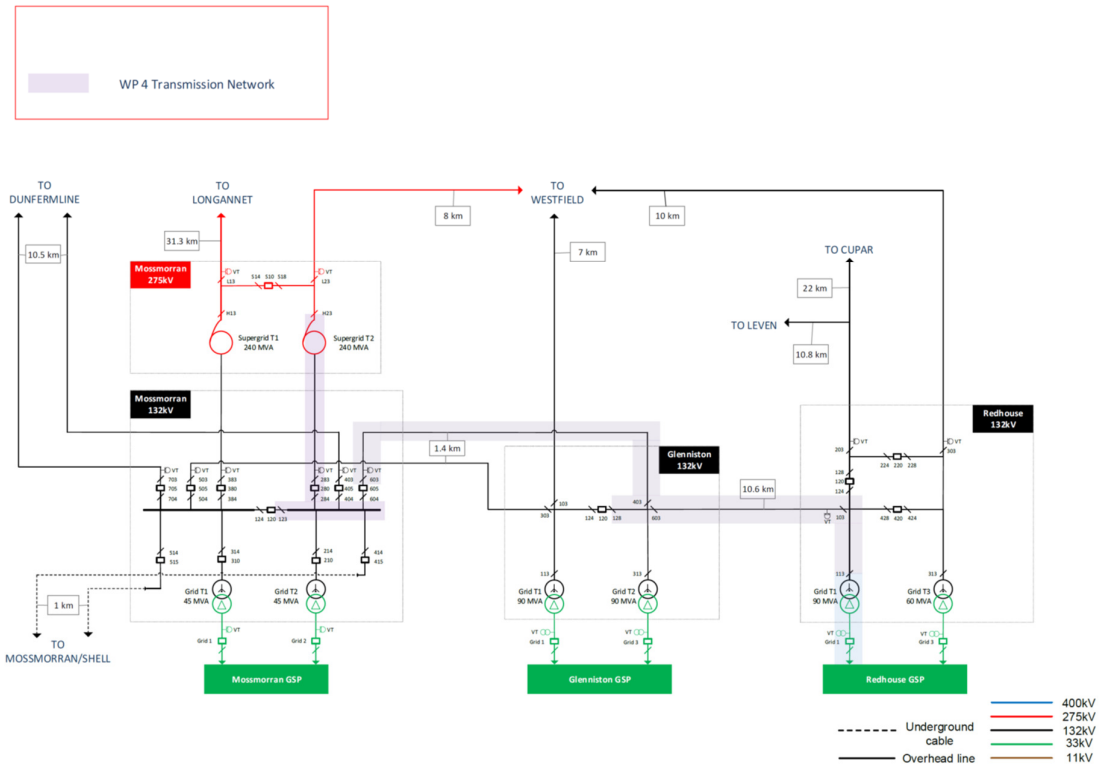


Figure A.2: Redhouse Transmission WP4 Test Diagram

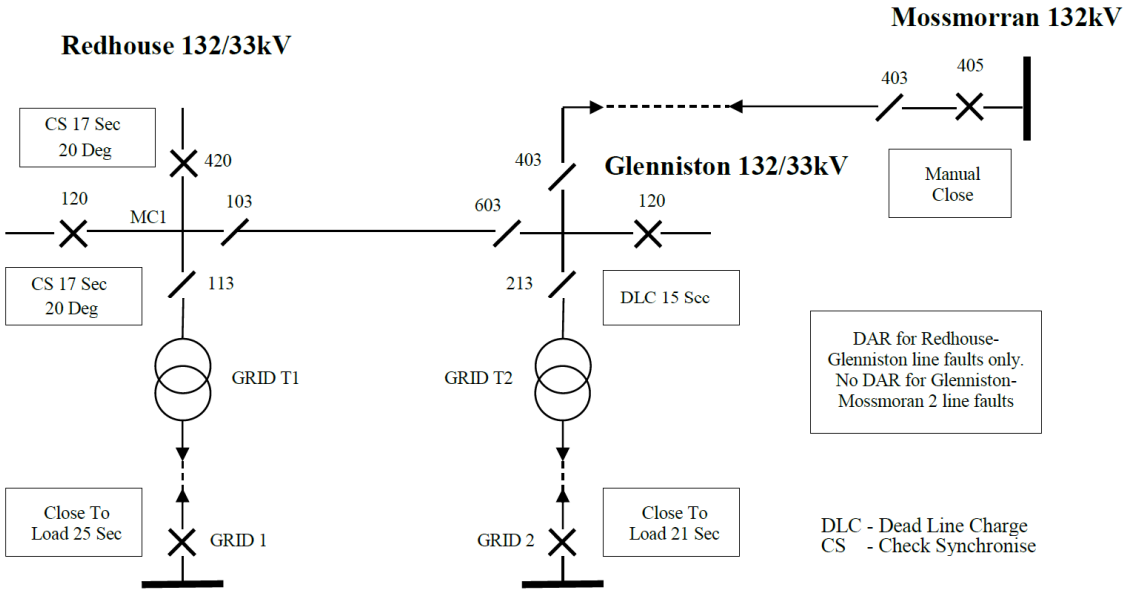


Figure A.3: Extract from 132 kV Protection and Auto Switching Datasheet

PROT-21-065 Issue 3 Redhouse - Glenniston - Mossmorran 2 132 kV Feeder

APPENDIX B

Existing Protection Settings

Substation	Circuit Name	Protection Function	Scheme Type	Device Type	Second Group Available	Voltage Control Available	Cold Load Pickup	Actual Settings	Reference
Redhouse 33 kV GSP	16 Redhouse Bess	Main Protection	OC	P14N	YES	YES	YES	800/1, 400A, SI, TM 0.3	Email received 14/4/21 with D Restart Project.doc attached, Email for BEF 14/5/21.
			EF					800/1, 120A, SI, TM 0.25	
	15 Glenrothes	Main Protection	BEF	Alstom MFAC				400/1, Vs = 75V, Rsh = 280 ohm	
		Backup Protection	OC	P14N	YES	YES	YES	400/1, 500A, SI, TM 0.4 HS = 3.2kA INST	
			EF					400/1, 80A, SI, TM 0.1	
	14 NOP Leven	Main Protection	BEF	Alstom MFAC				400/1, Vs = 75V, Rsh = 280 ohm	
		Backup Protection	OC	P14N	YES	YES	YES	400/1, 500A, SI, TM 0.4 HS = 2.4kA INST	
			EF					400/1, 80A, SI, TM 0.1	
	13 Birrel St Wynd 1	Main Protection	BEF	Alstom MFAC				400/1, Vs = 75V, Rsh = 280 ohm	
		Backup Protection	OC	P14N	YES	YES	YES	400/1, 500A, SI, TM 0.4 HS = 3.2kA INST	
			EF					400/1, 80A, SI, TM 0.1	
	12 Cluny 1	Main Protection	BEF	Alstom MFAC				400/1, Vs = 75V, Rsh = 280 ohm	
		Backup Protection	OC	P14N	YES	YES	YES	400/1, 500A, SI, TM 0.4 HS = 2.4kA INST	
			EF					400/1, 80A, SI, TM 0.1	
	11 Redhouse 1	Main Protection	BEF	Alstom MFAC				400/1, Vs = 75V, Rsh = 280 ohm	
		Backup Protection	OC	P14N	YES	YES	YES	400/1, 500A, SI, TM 0.4 HS = 3.2kA INST	
			EF					400/1, 80A, SI, TM 0.1	
	Grid T1	Transformer Feeder Protection	Directional OC	KCEG142	YES	NO	YES	528A, SI, TM 0.1, 45DEG	Email from Andrew MacKay, Email from Roxanne Aspin 17/6/21
			SBEF1	KCEG142	YES	NO	YES	1600/1, 160A, LTI, TM 0.225	
			SBEF2	KCEG142	YES	NO	YES	1600/1, 212A, LTI, TM 0.25	
			LVOC	KCEG142	YES	NO	YES	1600/1, 2208A, SI, TM 0.275	
			DIFFERENTIAL	Duobias 7SG24	YES	NO	NO	1600/1, W2 1.26x, Ydy0, 0deg, inrush enabled = 0.2Id, Is = 0.3x In, Slope 0.3x, Limit 10xIn, 0s, Highset enabled 10xIs, 0s	Email from Roxanne Aspin 17/6/21
			REF					1600/1, 0.1, 160A	
	Bus Section	Busbar Protection	OC	P14N	YES	YES	YES	1600/1, 1280A, SI, TM 0.275	Email received 14/4/21 with D Restart Project.doc attached
			EF					1600/1, 128A, SI, TM 0.35	
Redhouse GSP 132 kV	Glenniston	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	500/1,Is1 = 0.2A, Is2 = 2.3 A, k1 = 30%, k2 =100%, DT, 0s,	Email from Roxanne Aspin
		132 kV Feeder Backup Protection	OC (IDMT)	P14N	YES	YES	YES	500/1, 810A, SI, TM 0.4	Email from Roxanne Aspin, PROT-21-065 for relay type, 29/6/21
			EF (IDMT)					500/1, 400A, SI, TM 0.6	
		Mesh Corner (disconnector 103 open)	Connections Standby HSOC	P14N				500/1, 6000A, DT, 0s	
	Grid T1	Transformer Feeder Protection	OC	P14N	YES	YES	YES	500/1, 1.1A, 550A, SI, 0.35	Email from Roxanne Aspin
			DIFFERENTIAL	Duobias 7SG24	YES	NO	NO	500/1, W1 1.5x, Yd9, 90deg, inrush enabled = 0.2Id, Is = 0.3x In, Slope 0.3x, Limit 10xIn, 0s, Highset enabled 12xIs, 0s	Email from Roxanne Aspin (also in 33 kV section assumed W2)
			REF					500/1, Enabled 0.06x In, 0s	
Glenniston GSP 132 kV	Redhouse	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	500/1,Is1 = 0.2A, Is2 = 2.3 A, k1 = 30%, k2 =100%, DT, 0s,	Email from Roxanne Aspin
		132 kV Feeder Backup Protection	OC (IDMT)	P14N	YES	YES	YES	500/1, 810A, SI, TM 0.4	Emal from Andrew MacKay what is CSB 6000A,0s PBO relay type from PROT-21-065, clarified 17/6/21
			EF (IDMT)					500/1, 400A, SI, TM 0.6	
	Mossmorran	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	YES	YES	500/1,Is1 = 0.2A, Is2 = 2.3 A, k1 = 30%, k2 =100%, DT, 0s	Email from Roxanne Aspin, 17/6/21
		132 kV Feeder Backup Protection	OC (IDMT)	TJM10	NO	NO	NO	500/1, 810A, 0.4 TMS (old electromagnetic relay with plug bridge expect 1.5A setting 750A or 1.75A 875A)	PROT-21-065, email RA 17/6/21
		Bus Section Protection	OC (IDMT)	PBO	NO	NO	NO	500/1, 1.5A, 0.4 TMS	according to PROT-21-065, Email RA 17/6/21
Mossmorran GSP 132 kV	Glenniston	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	600/1,Is1 = 0.2A, Is2 = 2.3 A, k1 = 30%, k2 =100%, DT, 0s,	Email from Roxanne Aspin, PROT-21-065 500/1, 1200/2A Backup
			interlocked OC	P545	YES	NO	YES	600/1, I>0.4A, DT, TM= 0.4	Email from Roxanne Aspin, 17/6/21
		132 kV Feeder Backup Protection	OC (IDMT)	CDG31	NO	NO	NO	600/1, 1.5A, 0.4 TMS	PROT-21-065, email rA 17/6/21
	SGT2	Transformer Feeder Protection	OC (IDMT)	KCEG140	YES	NO	YES	600/1, 1.536kA, SI, TMS 0.35	Email from Roxanne Aspin, 17/6/21
			EF (IDMT)		YES	NO	YES	600/1, 120A, SI, TMS 1	Email from Roxanne Aspin, 17/6/21
		Busbar Protection	Supervisory/unit	FAC34	NO	N/A	N/A	V = 150V	Email for Roxanne Aspin, 29/6/21

Table B.1: Existing Protection Settings

APPENDIX C

Revised Relays & Settings

KEY	
	No Change
	Setting Change required
	New Relay or Solution not confirmed

Substation	Circuit Name	Protection Function	Scheme Type	Device Type	Second Group Available	Voltage Control Available	Cold Load Pickup	NEW RELAY REQUIRED	Rating	TRIAL SETTINGS	Report Section
Redhouse 33 kV GSP	16 Redhouse Bess	Main Protection	OC	P14N	YES	YES	YES	NO		800/1, 104A, DT, 0.3s	6.1.2
			EF							no change	6.1.2.2
	15 Glenrothes	Main Protection	BEF	Alstom MFAC				NO		no change	6.1.1.1
		Backup Protection	OC	P14N	YES	YES	YES	NO		no change	6.1.2
			EF							no change	6.1.2.2
	14 NOP Leven	Main Protection	BEF	Alstom MFAC				NO		no change	6.1.1.1
		Backup Protection	OC	P14N	YES	YES	YES	NO		no change	6.1.2
			EF							no change	6.1.2.2
	13 Birrel St Wynd 1	Main Protection	BEF	Alstom MFAC				NO		no change	6.1.1.1
		Backup Protection	OC	P14N	YES	YES	YES	NO		400/1, 100A, DT, 0.1s HS = 3.2kA INST	6.1.2
			EF							no change	6.1.2.2
	12 Cluny 1	Main Protection	BEF	Alstom MFAC				NO		no change	6.1.1.1
		Backup Protection	OC	P14N	YES	YES	YES	NO		400/1, 100A, DT, 0.1s HS = 2.4kA INST	6.1.2
			EF							no change	6.1.2.2
	11 Redhouse 1	Main Protection	BEF	Alstom MFAC				NO		no change	6.1.1.1
		Backup Protection	OC	P14N	YES	YES	YES	NO		400/1, 100A, DT, 0.1s HS = 3.2kA INST	6.1.2
			EF							no change	6.1.2.2
	Grid T1	Transformer Feeder Protection	Directional OC	KCEG142	YES	NO	YES	KCEG relay not suitable for voltage control		102A, DT,0.1s, 45DEG	6.2.2.1
			SBEF1	KCEG142	YES	NO	YES			no change	6.1.2.2
			SBEF2	KCEG142	YES	NO	YES			no change	6.1.2.2
			LVOC	KCEG142	YES	NO	YES			no change however could be used as backup would require reduction in settings	6.2.2.1.
			DIFFERENTIAL	Duobias 7SG24	YES	NO	NO	NO		1600/1, W2 1.26x, Ydy0, 0deg, inrush enabled = 0.2Id, Is = 0.1x In, Slope 0.3x, Limit 10xIn, 0s, Highset enabled 10xIs, 0s	6.2.1.3
			REF					NO		no change	6.1.1.2
	Bus Section	Busbar Protection	OC	P14N	YES	YES	YES	NO		no change	6.1.1.5
			EF							no change	

Table C.1: TRIAL 33 kV settings

Substation	Circuit Name	Protection Function	Scheme Type	Device Type	Second Group Available	Voltage Control Available	Cold Load Pickup	NEW RELAY REQUIRED	Rating	TRIAL SETTINGS	Report Section
Redhouse GSP 132 kV	Glenniston	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	YES		Settings not sensitive enough to detect faults	6.2.1.1
		132 kV Feeder Backup Protection	OC (IDMT)	P14N	YES	YES	YES	Possibly new CT for voltage control		no change	6.2.2.1
			EF (IDMT)							no change	6.2.2.2
		Mesh Corner (disconnector 103 open)	Connections Standby HSOC	P14N	YES	YES	YES	NO		no change	6.2.2.1
	Grid T1	Transformer Feeder Protection	OC	P14N	YES	YES	YES	Possibly new CT for voltage control		500/1, 0.08A, 40A, DT 0.1s changed to pickup for earth fault	6.2.2.2
			DIFFERENTIAL	Duobias 7SG24	YES	NO	NO	NO		500/1, W1 1.5x, Yd9, 90deg, inrush enabled = 0.2Id, Is = 0.1x In, Slope 0.3x, Limit 10xIn, 0s, Highset enabled 12xIs, 0s	6.2.1.3
			REF					NO		no change	6.2.1.4
Glenniston GSP 132 kV	Redhouse	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	YES		Settings not sensitive enough to detect faults	6.2.1.1
		132 kV Feeder Backup Protection	OC (IDMT)	P14N	YES	YES	YES	Possibly new CT for voltage control		no change	6.2.2.1
			EF (IDMT)							no change	6.2.2.2
	Mossmorran	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	YES	YES	YES		Settings not sensitive enough to detect faults	6.2.1.1
		132 kV Feeder Backup Protection	OC (IDMT)	TJM10	NO	NO	NO	voltage control option not available		no change	6.2.2.1
		Bus Section Protection	OC (IDMT)	PBO	NO	NO	NO	NO		no change	-
Mossmorran GSP 132 kV	Glenniston	132 kV Feeder Main Protection	132 kV Unit (overhead circuits)	P545	YES	NO	NO	YES		Settings not sensitive enough to detect faults	6.2.1.1
			interlocked OC	P545	YES	NO	YES	voltage control option not available		no change	6.2.2.1
		132 kV Feeder Backup Protection	OC (IDMT)	CDG31	NO	NO	NO			no change	6.2.2.1
	SGT2	Transformer Feeder Protection	OC (IDMT)	KCEG140	YES	NO	YES			no change	6.2.2.1
			EF (IDMT)		YES	NO	YES			no change	6.2.2.2
		Busbar Protection	Supervisory/unit	FAC34	NO	N/A	N/A	NO		no change	-

Table C.2: Trial 132 kV settings

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