Adaptive Protection Installation and Specification Report

30 September 2016

CONTENTS

VERSION HISTORY

Version	Date	Author	Status	Comments
V1.0	27 September 2016	S. Stott	Final	

APPROVAL

Name	Role	Date
Steve Stott (Author)	Lead Innovation Delivery Engineer	27/09/16
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GLOSSARY OF TERMS

Abbreviation	Description
ADMS	Advanced Distribution Management System
AP	Adaptive Protection
CB	Circuit Breaker
CFS	Core Function Service
CRMS	Control Room Monitoring System
DMD	Dynamic Mimic Diagram
DMS	Distribution Management System
DNO	Distribution Network Operator
FAT	Factory Acceptance Testing
FCLS	Fault Current Limiting Service
FLAT	Fault Level Assessment Tool
FSA	Functional Spares Assembly
ICCP	Inter Control Communications Protocol
LCNF	Low Carbon Network Fund
NDS	Network Dynamic Service
MTS	Model Topology Service
NMS	Network Management System
NMS	Network Management System
Ofgem	Office of Gas and Electricity Markets
RTU	Remote Terminal Unit
SAT	Site Acceptance Testing
SDRC	Successful Delivery Reward Criteria
UI	User Interface

All other definitions shown starting with a capital letter are as per LCN Fund Governance Document v6.

1 EXECUTIVE SUMMARY

This report is one of a series of documents, submitted as part of Electricity North West's Second Tier Low Carbon Networks (LCN) Fund project, Respond. Electricity North West received formal notification of selection for funding on 24 November 2014. The project will run for 46 months, starting in January 2015 and finishing in October 2018.

Respond seeks to demonstrate the viability and effectiveness of near real time fault level assessment and adaptive mitigation techniques to overcome fault level challenges faced by distribution network operators (DNOs).

The Ofgem Project Direction document outlines certain successful delivery reward criteria (SDRC), against which the success of the Respond project will be assessed. For each criterion, the Project Direction defines the evidence that is required to demonstrate successful delivery.

There are SDRC reports for the technology installation phase of the project and this report is the document to deliver evidence on the SDRC stated below.

- Publish equipment specification and installation report for Adaptive Protection by September 2016.

2 INTRODUCTION

Respond is investigating how fault current on distribution networks can be managed by the use of various techniques which in turn are selected by a near real time fault level assessment tool (FLAT). The FLAT calculates fault level on a periodic (every five minutes) or network topology basis (network switching operations). It can select one of three techniques:

- I_S-limiter in series with a primary substation transformer or across an open 11kV bus-section circuit breaker (CB).
- Adaptive Protection (AP) which during a fault reduces fault current by opening an 11kV bus-section CB before the downstream 11kV CB has been issued with a trip command from its' protection relay.
- Enabling a Fault Current Limiting Service (FCLS) from customers generators and motors, which causes these devices protection relays to trip their respective CBs more rapidly than normal in order reduce their fault current contribution to a fault on the DNO system.

Extensive Respond trials are planned to assess the FLAT tool and the previously described on-site techniques for their performance and frequency of operation. Trial results will enable the evaluation of the various Respond principles.

This report shows the methodology used when installing the Adaptive Protection relays which is required on site for this approach to work. The scope of the work is to prove that the new adaptive protection relays can communicate correctly with the SCADA system (telecontrol, CRMS, NMS and the FLAT tool), locally monitor on site CB status to prevent unnecessary loss of supply and measure total upstream fault current contribution accurately.

3 ADAPTIVE PROTECTION INSTALLATION TYPES

To enable the maximum amount of learning during the trial period the selected sites were split up into different installation types.

It should be noted that some of the substations primary distribution boards are 6.6kV rather than the more usual 11kV, however to reduce the need for repetition wherever 11kV is stated in this document it applies to both 6.6kV and 11kV.

3.1 Type 1

This type consisted of a primary substation which did not have any protection relays fitted to the 11kV bus-section CB current transformers (CT). In order to measure the total upstream fault current, interposing current transformers (IPCT) were fitted in series with the secondary wiring of the two 33/11kV primary transformer overcurrent CTs. The output of the IPCTs on both transformers was summated and fed into the AP relay fitted in a new wall mounted box. The AP relay installed in this type of installation was an AREVA P145 overcurrent and earth-fault numeric relay. Figure 1 below shows the AP setup for a primary without any closed rings across the 11kV bus-section which allows the 11kV bus-section CB to be tripped. Figure 2 shows the AP setup for a primary with closed rings across the bus-section which requires one of the transformers CB's to be tripped.

Figure 1: Type 1 Adaptive Protection Installation with open rings on 11kV system

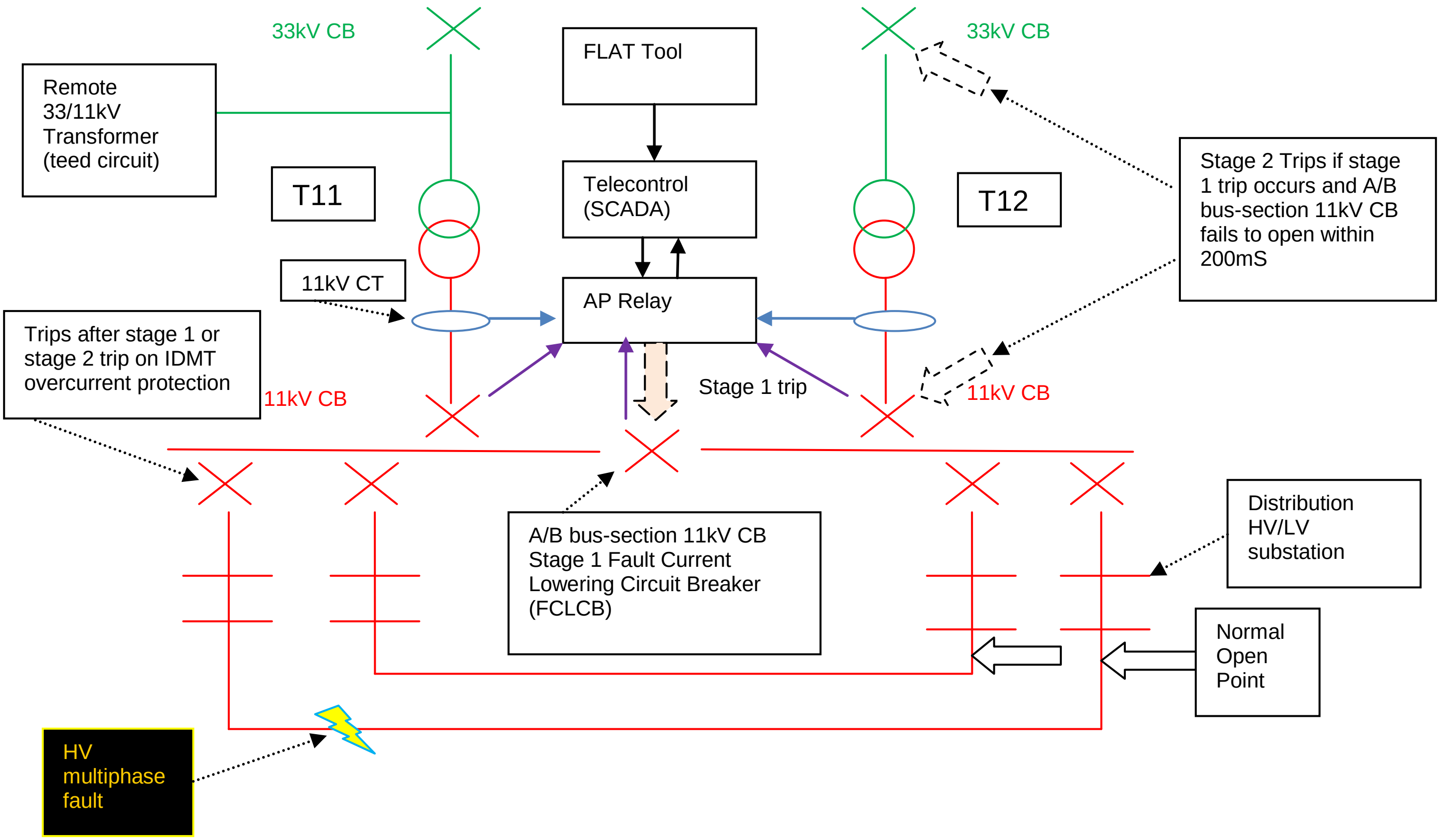
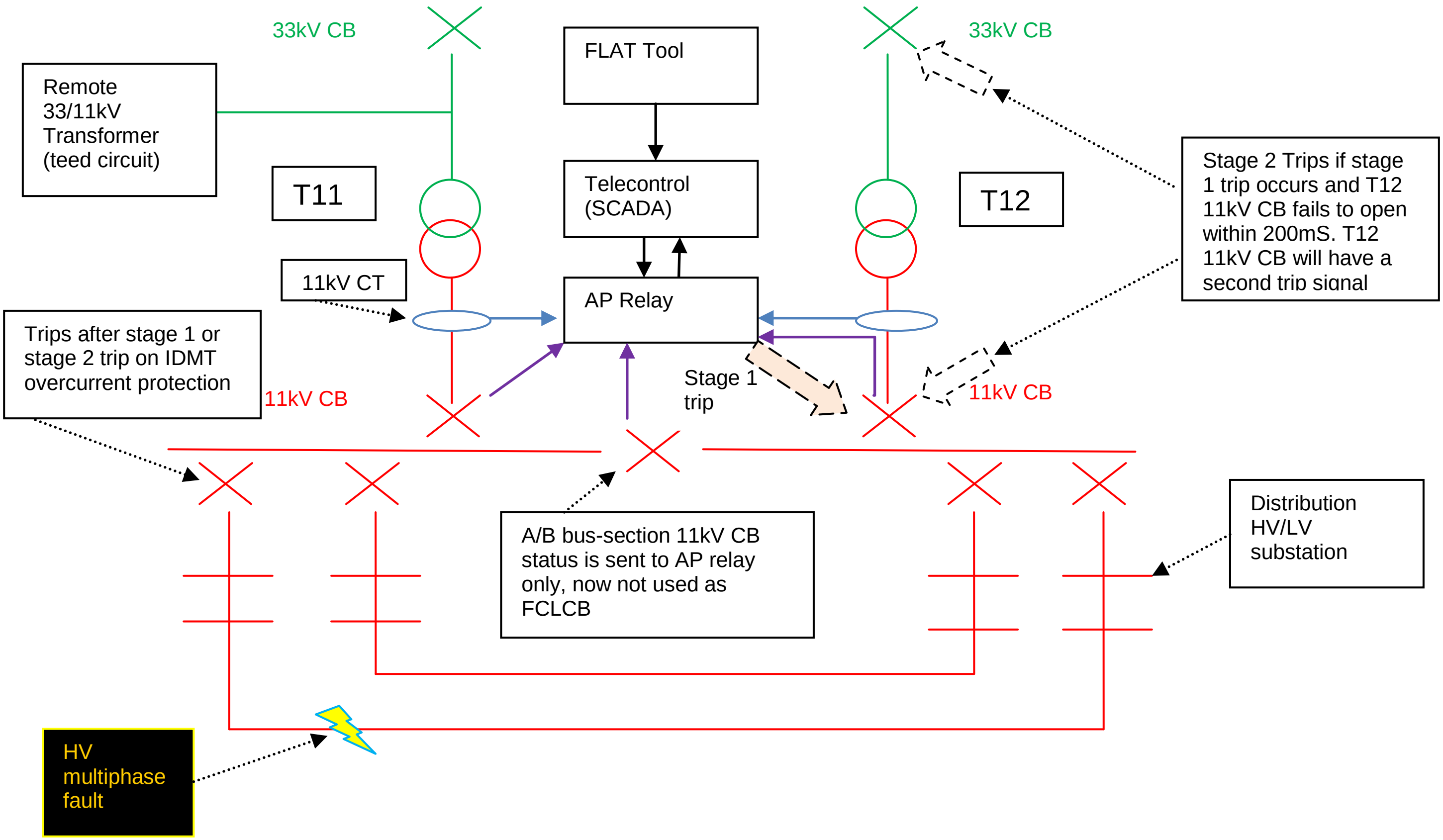


Figure 2 - Type 1 Adaptive Protection Installation with closed rings on 11kV system



The AP relay cannot be enabled to operate unless the following pre-requisites are met.

- The AP relay is powered by an 110v DC supply.
- The self-checking process in the AP relay confirms it is in a “Healthy” condition.
- The on site AP ON/ OFF switch is in the “ON” position.
- The telecontrol (SCADA) AP IN/ OUT latching interposing relay is in the “IN” state.
- The AP relay locally confirms that the correct site topology conditions are correct i.e. T11 transformer, T12 transformer & Bus Section 11kV CBs are all closed.

Once the above pre-requisite conditions are met then the AP relay can be enabled in one of two ways.

- If the AP relay has not received a FLAT “HOLD OFF” signal from telecontrol (SCADA) before its internal fail-safe timer has operated (five minutes) then the AP relay will assume a loss of telecontrol/ NMS/ FLAT has occurred and will “fail-safe” and enable the AP relay. If any of the pre-requisites (A-E) change then AP will automatically be disabled.

- If the network topology changes in such a way that the FLAT tool calculates the fault level to have risen above the upper threshold value then it will send via telecontol a “FLAT ENABLE” signal to the AP relay. This could occur just after a FLAT “HOLD OFF” signal has been received by the AP relay. In this case the AP relay will change within 1 second to being enabled without waiting for its timer (five minutes) to operate. If, subsequent to this, any of the pre-requisites (A-E) change then AP will automatically be disabled. If the network topology changes again and the FLAT tool calculates the fault level to have dropped to below the lower threshold value then it will send via telecontol a “FLAT HOLD OFF” signal to turn off AP mode in the relay.

Once the AP relay is enabled it then measures the summated upstream current contribution of the two primary transformers on a per phase basis i.e. T11 + T12 11kV currents. Above a preset value of this summated upstream current contribution (usually 4500A) the AP relay will send, without intentional additional time delay, a trip signal to the fault level reducing circuit breaker (FLRCB).

The summated upstream current FLRCB trip value is chosen so that it will operate for the majority of multiphase faults on the HV system without any risk of operating for a single phase to earth fault (HV system is resistively earthed) or for load. With a setting of 4500A under equal operating conditions each primary transformer is likely to contribute 2250A. This current value of 2250A equates to 42.87MVA at 11kV and 25.72 MVA at 6.6kV from each of the primary transformers.

The AP relay has a 2/3 phase fault logic function which is designed to prevent any operation of the overcurrent protection (which the AP relay uses to operate the FCLCB) unless 2/3 phases have a measured value above the overcurrent setting on the AP relay.

On some GB DNO HV systems direct earthing of the primary transformers is used. As such a single phase to earth fault may be larger in magnitude than some multiphase faults (up to 15.5% larger than a two phase fault). In these circumstances the DNO would need to set the AP overcurrent setting to a value which operates to reduce fault level for a chosen level of multiphase faults but discriminates against tripping for load current without trying to discriminate against operation for earth faults. The 2/3 logic function could be disabled to cater for the significant potential phase to earth fault currents. Alternatively the earth fault element of the AP relay could be utilised (not used in Respond) to trip the FCLCB at lower levels of fault current than the maximum load level.

The FCLCB was chosen according to the following rules.

- For HV systems without 11kV closed ring circuits connected across the primary 11kV bus-section CB the FCLCB shall be the 11kV bus-section CB.
- For HV systems with 11kV closed ring circuits connected across the primary 11kV bus-section CB the FCLCB shall be a T11 or T12 11kV CB. A primary transformer which has sole use of its 33kV circuit is preferred i.e. not a teed 33kV circuit.

The logic behind the above rule is that it is preferable to open the 11kV bus-section CB as there are two 33kV transformer circuits feeding into the primary after the fault level has been reduced. Opening a transformer CB increases the risk of losing supplies to the whole primary substation in event of a second fault or CB failure such as a stuck breaker. In case the 11kV bus-section CB fails to trip a back-up second stage of FCLCB was fitted. On Respond the trip relay for either T11 or T12 (varies from site based on criteria explained latter) is operated if the 11kV bus-section CB fails to open 200mS after a stage 1 trip (to the 11kV bus-section CB) has been issued. This results in only one of the two primary transformers feeding into the fault and also reduces the risk of the second stage failing by the act of using the trip relay to trip both the 11kV and 33kV transformer CBs at the same time. Another approach would be to use 3 stages rather than the 2 used in Respond. This would result in the 3rd stage (33kV trip) being time delayed to a point whereby the risk of the outgoing 11kV CB opening at the same time or before the 33kV CB opening, and thus reducing its fault current contribution to a sufficiently low level, become to great.

When a primary substation has 11kV closed ring circuits connected across the primary 11kV bus-section CB (such as C2C or Translay circuits) using the 11kV bus-section CB as the FCLCB becomes less desirable. The closed 11kV rings may, depending on circuit impedances, effectively short out the 11kV bus-section CB thus reducing or eliminating the fault current magnitude reduction when opening this CB. The closed rings would also mean that the use of a back-up second stage of FCLCB would either be ineffective, for the same reasons as the first stage of FCLCB operation would be, or would necessitate that both T11 and T12 would need to be used as a second stage trip losing supplies to the whole primary substation. In this case it is preferable to use either T11 or T12 11kV CB as the FCLCB with the second stage tripping the 33kV CB of the same transformer, thus maintaining supplies until the normal IDMT/ blocked IDMT protection would operate for a stuck outgoing 11kV primary feeder CB.

The choice of second stage FCLCB is based on the following order of (decreasing) preference.

- A primary transformer which has sole use of its 33kV circuit and is within the same substation grounds as the 11kV CB i.e. not a remote 33kV CB using intertripping or fault throwing.
- A primary transformer which has sole use of its 33kV circuit whose 33kV CB is not in the same substation grounds as the 11kV CB and uses communications for remote tripping i.e. not a teed 33kV circuit/ uses intertripping but not fault throwing.
- A primary transformer which shares its 33kV circuit (teed 33kV circuit) and is within the same substation grounds as the 11kV CB i.e. not a remote 33kV CB which uses intertripping or fault throwing.
- A primary transformer which has sole use of its 33kV circuit whose 33kV CB is not in the same substation grounds as the 11kV CB and uses a fault thrower to operate the remote 33kV CB i.e. not a teed 33kV circuit/ has no intertripping but uses fault thrower.
- A primary transformer which shares its 33kV circuit (teed 33kV circuit) and uses a fault thrower to operate the remote 33kV CB i.e. a teed 33kV circuit/ has no intertripping but uses fault thrower.

List of Type 1 sites

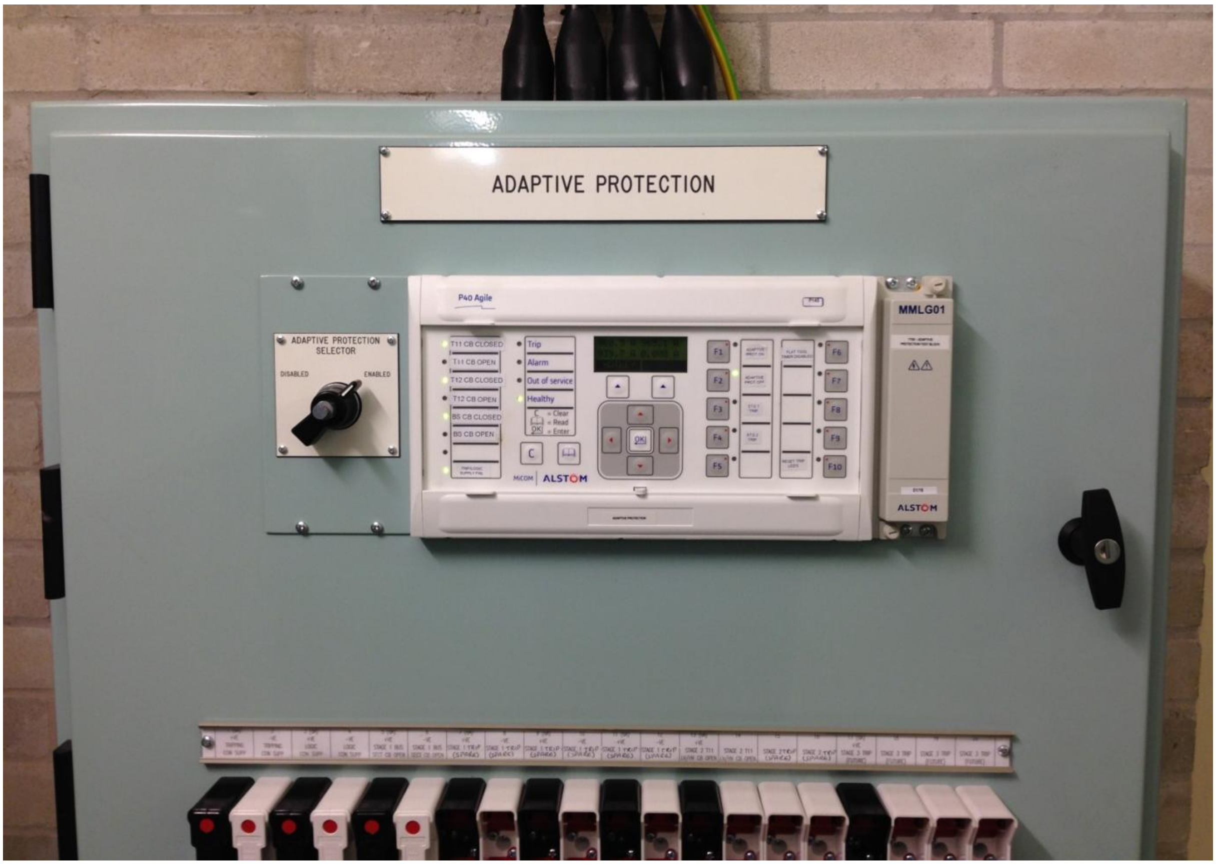
Atherton TC Primary S/S

Denton West Primary S/S

Irlam Primary S/S

Littleborough Primary S/S

Photograph 1: Type 1 installation showing Adaptive Protection Wall Mounted Box



Photograph 2: Type 1 installation showing Interposing Current Transformers (IPCT) boxes mounted on top of T11 and T12 11kV Protection panels at Irlam Primary.

Photograph 3: Type 1 installation showing A/B 6.6kV bus-section Circuit Breaker used for Stage 1 Adaptive Protection trip. Unit is removed from service for profiler tests.

Photograph 4: Type 1 installation showing A/B 6.6kV bus-section Circuit Breaker used for Stage 1 Adaptive Protection trip. Unit is in service for partial discharge bench marking tests prior to the Respond trials.

3.2 Type 2

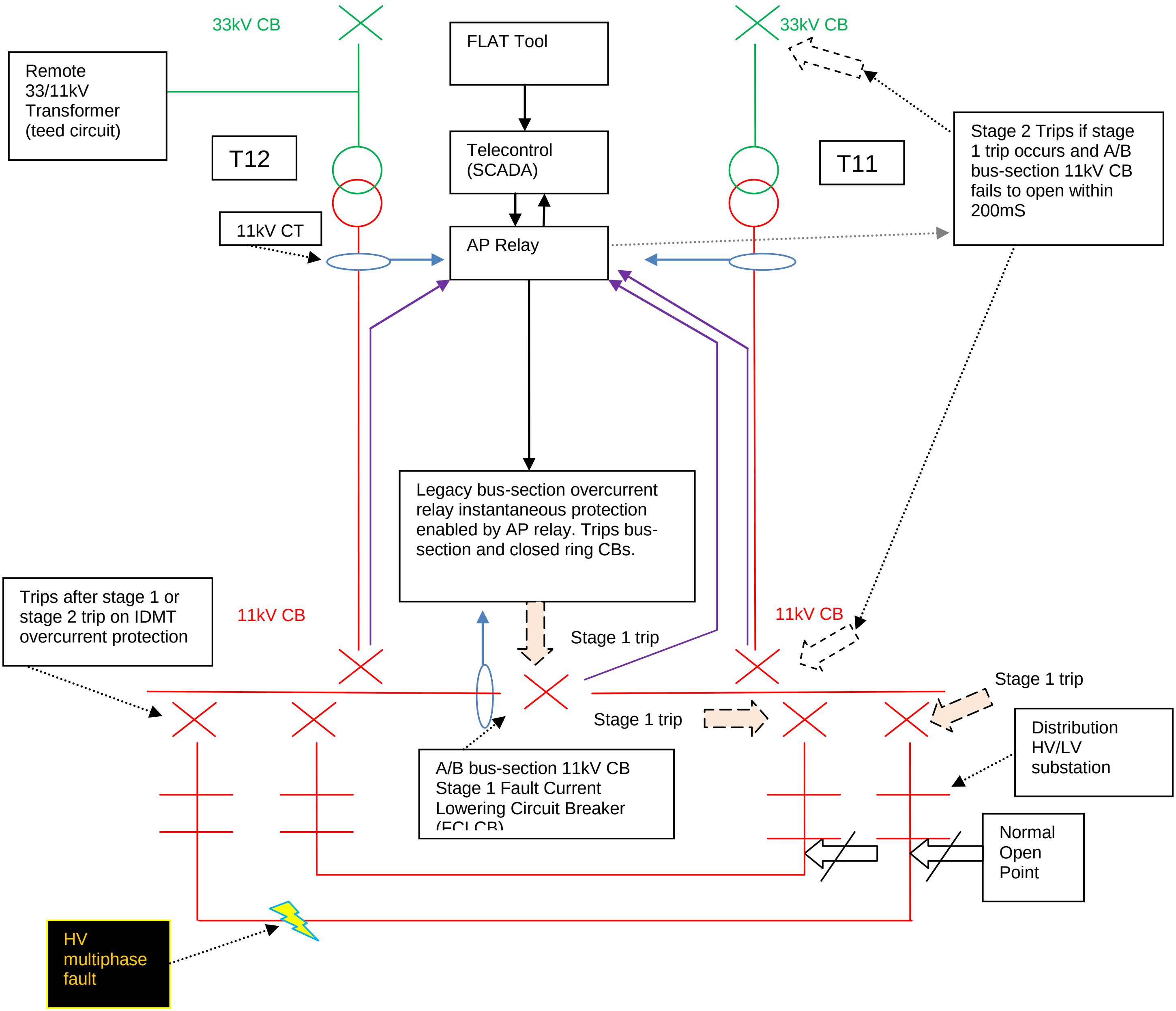
This type consisted of a primary substation which did have protection relays fitted to the 11kV bus-section CB current transformers (CT). The AP relay measures the total upstream fault current contribution but rather than trip the A/B 11kV bus-section CB direct it releases a blocking input on the legacy (numeric) bus-section overcurrent relay. With this blocking input removed an instantaneous overcurrent element is allowed to trip the A/B 11kV bus-section CB itself. The normal overcurrent trip on this legacy relay is time delayed and would not be suitable for fault level reduction due to the length of the delay.

Modern sites of this type fitted with numeric relays would generally have a blocking scheme fitted. Blocking schemes would appear to give a cost-effective method of adaptive protection without the need for extra protection relays. Such a system could be modified, via means of telecontrol interposing relays, to disable the downstream blocks to the T11/ T12/ bus-section 11kV CBs when the AP mode was required. At some of the bid prescribed Respond sites the legacy relays deployed used a combined overcurrent and earth-fault blocking system. As these two blocking signals are sent on the same wires and do not use any coding (voltage level only) the use of adaptive protection would cause the stage 1 trip to operate for earth faults as well as multiphase faults. It would be unlikely that this would be in the spirit of the Respond project as it would lead to unnecessary operation of the A/B 11kV bus-section CB. In GB it is generally considered that around 80% of HV faults initiate as single phase to earth faults. Earth-faults on resistively earthed HV systems are virtually never of such a magnitude as to warrant any kind of fault current reduction techniques. As such it is likely that by disabling a blocking signal used for all types of fault this type of AP system would operate around five times more often than necessary. Where a DNO solidly earths the HV system then it may be that fault current reduction during earth-faults is required. In such combined overcurrent and earth-fault blocking schemes the DNO should consider the removal of any blocking signals to the transformer (on closed ring) or A/B bus-section 11kV (on open ring 11kV systems) protection relays via series fitted interposing relays when AP mode is required.

In order for the AP relay to measure the total upstream fault current, interposing current transformers (IPCT) were fitted in series with the two 33/11kV primary transformers (named T11 and T12) 11kV overcurrent protection CTs secondary (output) wiring. The output of the IPCTs on T11 and T12 was summated and fed into the Adaptive Protection (AP) relay fitted in a new wall mounted box.

The AP relay installed in this type of installation was an AREVA P145 overcurrent and earth-fault numeric relay. This relay measured the total (summated) upstream current contribution from the T11 & T12 11kV transformer outputs into their respective cable boxes and hence through their respective 11kV CBs. This summated current is the upstream contribution to any fault on the primary substation 11kV busbars or any of the outgoing distribution 11kV feeders.

Figure 3 - Type 2 Adaptive Protection installation



The AP relay cannot be enabled to operate unless the following pre-requisites are met.

- The AP relay is powered by an 110v DC supply.
- The self-checking process in the AP relay confirms it is in a “Healthy” condition.
- The on site Adaptive Protection ON/ OFF switch is in the “ON” position.
- The telecontrol (SCADA) Adaptive Protection IN/ OUT latching interposing relay is in the “IN” state.
- The AP locally confirms that the correct site topology conditions are correct ie T11, T12 & Bus Section 11kV CBs are all closed.
- The AP relay cannot be enabled to operate unless the following pre-requisites are met.

Once the above pre-requisite conditions are met then the AP relay can be enabled in one of two ways.

- If the AP relay has not received a FLAT “HOLD OFF” signal from telecontrol (SCADA) before its internal fail-safe timer has operated (five minutes) then the AP relay will assume a loss of telecontrol/ NMS/ FLAT has occurred and will “fail-safe” and enable the AP relay. If any of the pre-requisites (A-E) change then AP will automatically be disabled.
- If the network topology changes in such a way that the FLAT tool calculates the fault level to have risen above the upper threshold value then it will send via Telecontol a “FLAT ENABLE” signal to the AP relay. This could occur just after a FLAT “HOLD OFF” signal has been received by the AP relay. In this case the AP relay will change within 1 second to being enabled without waiting for its timer (five minutes) to operate. If any of the pre-requisites (A-E) change then AP will automatically be disabled. If the network topology changes again and the FLAT tool calculates the fault level to have dropped to below the lower threshold value then it will send via Telecontol a “FLAT HOLD OFF” signal to turn off AP mode in the relay.

Once the AP relay is enabled it then measures the summated upstream current contribution of the two primary transformers i.e. T11 + T12 11kV currents. Above a preset value of this summated upstream current contribution (usually 4500A) the AP relay will release the stage 2 overcurrent high set protection blocking signal, without intentional additional time delay. The release of this blocking signal allows the A/B 11kV bus-section protection relay to trip it’s CB which as far as the adaptive protection system is concerned is the fault level reducing circuit breaker (FLRCB). In addition it is common for sites with numeric protection to have some closed HV ring circuits (C2C/ Translay/ directional protection) across the A/B 11kV bus-section. Regardless of the presence of adaptive protection the closed ring circuits are normally tripped if the bus-section protection operates. When adaptive protection is fitted this remains the case.

The A/B 11kV bus-section CB 2nd stage overcurrent protection, which the AP relay enables when it sees 4500A of summated upstream fault current contribution, is set to 2250A with no intentional additional time delay.

The summated upstream current FLRCB trip value is chosen so that it will operate for the majority of multiphase faults on the HV system without significant risk of operating for a single phase to earth fault (HV system is resistively earthed) or for load. With a setting of 4500A under equal operating conditions each primary transformer is likely to contribute 2250A. This current value of 2250A equates to 42.87MVA at 11kV and 25.72 MVA at 6.6kV from each of the primary transformers.

It is worth noting that the AP relay has a 2/3 phase fault logic function which is designed to prevent any operation of the overcurrent protection (which the AP relay uses to operate the FCLCB) unless 2/3 phases have a measured value above the overcurrent setting on the AP relay.

On some GB DNO HV systems direct earthing of the primary transformers is used. As such a single phase to earth fault may be larger in magnitude than some multiphase faults (up to 15.5% larger than a two phase fault). In these circumstances the DNO would need to set the AP overcurrent setting to a value which operates to reduce fault level for a chosen level of multiphase faults but discriminates against tripping for load current without trying to discriminate against operation for earth faults. The 2/3 logic function could be disabled to cater for the significant potential phase to earth fault currents. Alternatively the earth fault element of the AP relay could be utilised (not used in Respond) to trip the FCLCB at lower levels of fault current than the maximum load level.

The logic behind using the A/B 11kV bus-section CB as the FCLCB is that it is preferable to open this CB as there are two 33kV transformer circuits feeding into the primary after the fault level has been reduced. Opening a transformer CB increases the risk of losing supplies to the whole primary substation in second fault or CB failure conditions. An example of a second fault may be the loss of the remaining primary transformer and a CB failure would include the failure to open (stuck CB) of an outgoing 11kV feeder CB at the primary whose protection had detected a fault on it. In case the 11kV bus-section CB fails to trip a back-up second stage of FCLCB needs to be fitted. On Respond the trip relay for either T11 or T12 (varies from site based on criteria explained latter) is operated if the 11kV bus-section CB fails to open 200mS after a stage 1 trip (to the 11kV bus-section CB) has been issued. This results in only one of the two primary transformers feeding into the fault and also reduces the risk of the second stage failing by tripping both the 11kV and 33kV transformer CBs at the same time. Another approach would be to use 3 stages rather than the 2 used in Respond. This would result in the 3rd stage (33kV trip) being time delayed to a point whereby the risk of the outgoing 11kV CB opening at the same time or before the 33kV CB opening and reducing its fault current contribution to a sufficiently low level become to great.

When a primary substation has 11kV closed ring circuits connected across the primary 11kV bus-section CB (such as C2C or Translay circuits) using the 11kV bus-section CB as the FCLCB would normally becomes less desirable. The closed 11kV rings may, depending on circuit impedances, effectively short out the 11kV bus-section CB thus reducing or eliminating the fault current magnitude reduction when opening this CB. The closed rings would also mean that the use of a back-up second stage of FCLCB would either be ineffective, for the same reasons as the first stage of FCLCB operation would be, or would necessitate that both T11 and T12 would need to be used as a second stage trip losing supplies to the whole primary substation. In this case it is preferable to use either T11 or T12 11kV CB as the FCLCB with the second stage tripping the 33kV CB of the same transformer, thus maintaining supplies until the normal IDMT/ blocked IDMT protection would operate for a stuck outgoing 11kV primary feeder CB. However Type 2 sites have legacy numeric protection relays which measure fault current through the A/B 11kV bus-section CB and have closed ring stage 1 trips already fitted. In this case it is sensible to integrate adaptive protection with the legacy system.

The choice of second stage FCLCB is based on the following order of reducing desirability.

- A primary transformer which has sole use of its 33kV circuit and is within the same substation grounds as the 11kV CB i.e. not a remote 33kV CB using intertripping or fault throwing.
- A primary transformer which has sole use of its 33kV circuit whose 33kV CB is not in the same substation grounds as the 11kV CB and uses communications for remote tripping i.e. not a teed 33kV circuit/ uses intertripping but not fault throwing.
- A primary transformer which shares its 33kV circuit (teed 33kV circuit) and is within the same substation grounds as the 11kV CB i.e. not a remote 33kV CB which uses intertripping or fault throwing.
- A primary transformer which has sole use of its 33kV circuit whose 33kV CB is not in the same substation grounds as the 11kV CB and uses a fault thrower to operate the remote 33kV CB i.e. not a teed 33kV circuit/ has no intertripping but uses fault thrower.

- A primary transformer which shares its 33kV circuit (teed 33kV circuit) and uses a fault thrower to operate the remote 33kV CB i.e. a teed 33kV circuit/ has no intertripping but uses fault thrower.

List of Type 2 Sites

Blackbull Primary S/S

Photograph 5

Photograph 6

Photograph 7

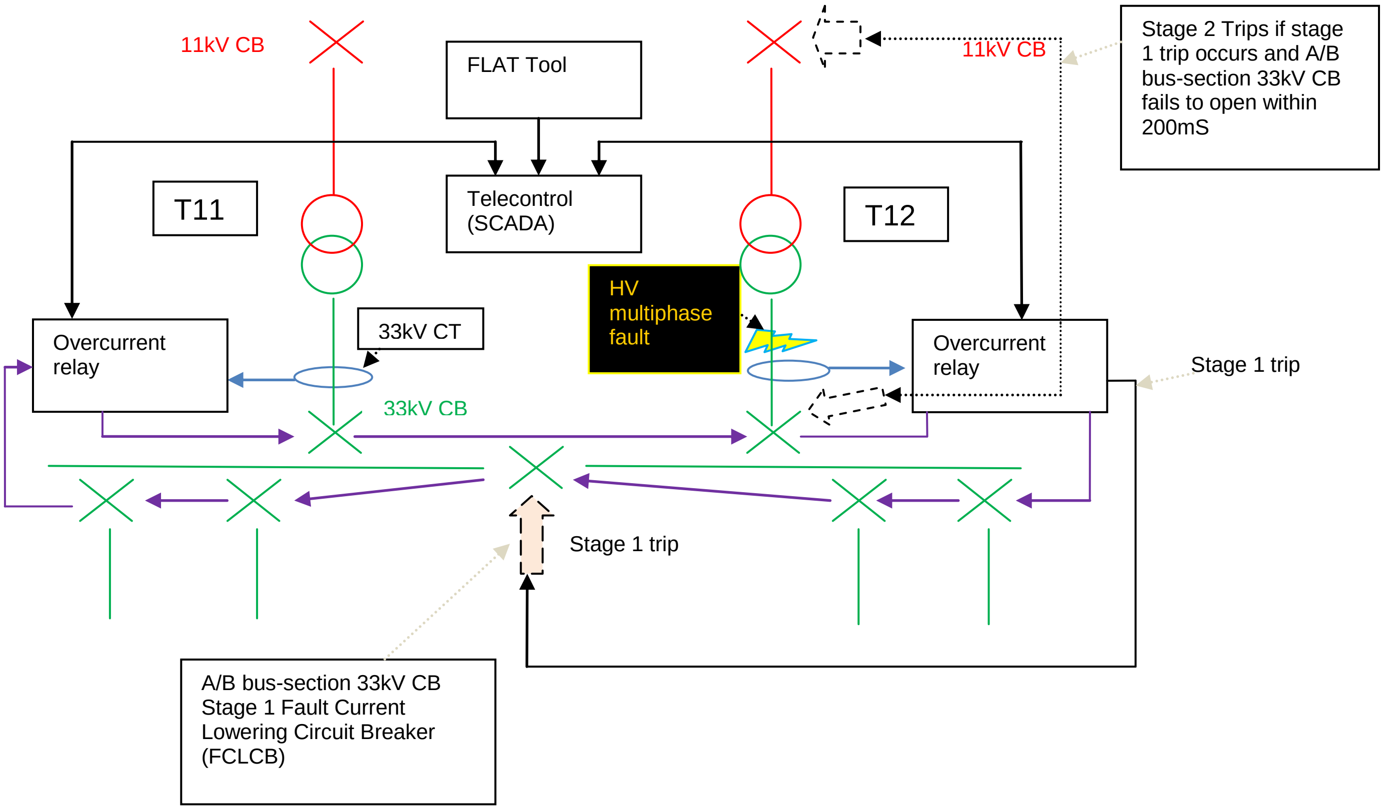
3.3 Type 3

This type consisted of a primary substation which did not have any numeric protection relays fitted to the 33kV bus-section CB current transformers (CT). In order to measure the total upstream fault current, interposing current transformers (IPCT) were fitted in series with the two 33/11kV primary transformers (named T11 and T12) 33kV overcurrent protection CTs secondary (output) wiring.

There was no single AP relay installed in this type of installation however two AREVA P145 overcurrent and earth-fault numeric relays were installed to replace legacy 33kV electromechanical protection on T11 and T12.

This relay measures the upstream current contribution from the 33kV system onto T11 or T12 33kV transformer inputs.

Figure 4 - Type 3 Adaptive Protection Installation for 33kV system



The T11 and T12 33kV Overcurrent relays (from now on referred to as AP relays) cannot be put into AP mode unless the following pre-requisites are met.

- The T11/T12 AP relays are powered by an 110v DC supply.
- The self-checking process in the AP relays confirms it is in a "Healthy" condition.
- The on site AP ON/ OFF switch is in the "ON" position (fitted to 33kV bus-section protection panel).
- The telecontrol (SCADA) AP IN/ OUT latching interposing relay is in the "IN" state.
- The correct site topology conditions are correct i.e. T11, T12 & Bus Section 33kV CBs are all closed and the other 33kV CBs are in their normal state i.e. they are not in a discrepancy condition which is set by an new AP discrepancy switch on each panel.

Once the above pre-requisite conditions are met then the AP relay can be enabled in one of two ways.

- If the AP relays have not received a FLAT "HOLD OFF" signal from telecontrol (SCADA) before its internal fail-safe timer has operated (five minutes) then the AP relays will assume a loss of telecontrol/ NMS/ FLAT has occurred and will "fail-safe" and enable the AP relays. If any of the pre-requisites (A-E) change then AP will automatically be disabled.
- If the network topology changes in such a way that the FLAT tool calculates the fault level to have risen above the upper threshold value then it will send via Telecontol a "FLAT ENABLE" signal to the AP relays. This could occur just after a FLAT "HOLD OFF" signal has been received by the AP relays. In this case the AP relays will change within 1 second to being enabled without waiting for its timer (five minutes) to operate. If any of the pre-requisites (A-E) change then AP will automatically be disabled. If the network topology changes again and the FLAT tool calculates the fault level to have dropped to below the lower threshold value then it will send via Telecontol a "FLAT HOLD OFF" signal to turn off AP mode in the relay.

Once the AP relays are enabled they then measure the summated upstream current contribution of their respective primary transformers i.e. T11 / T12 33kV currents. Above a preset value of this upstream current contribution (usually 2500A) the AP relays will operate their stage 2 overcurrent high set, without intentional additional time delay and trip the 33kV bus-section CB hence reducing 33kV fault current contribution into the 33kV side of the transformer.

Should the 33kV bus-section CB fail trip within 200mS then the stage 2 protection operates the trip relay on the transformer which has seen the fault current. This trips the transformer 33kV and 11kV CBs.

List of Type 3 Sites

Mount St Primary S/S

Offerton Primary S/S

4 COMMISSIONING TEST EQUIPMENT

The following calibrated and safety tested devices were used when commissioning the Adaptive Protection P145 relays, associated telecontrol interposing relays and CT/secondary burden.

OMICRON CMC 156

A PC-controlled test set which generates the test signals digitally (DSP technology), resulting in highly accurate testing signals even at small amplitudes.

Megger

Handheld insulation resistance and continuity tester

Multimeter

Handheld device with basic features such as the ability to measure voltage, current, and resistance

5 COMMISSIONING STRATEGY

Network outages were required for the commissioning of the Adaptive Protection relays, any new overcurrent relays and the communication path to telecontrol (SCADA). The strategy was to initialise the new overcurrent and Adaptive Protection relays with logic mapping and settings prior to the outages. Any existing overcurrent relay settings which were to be replaced had their setting transferred over to the new overcurrent relays as their group 1 settings.

For all types of installation (Types 1, 2, 3) the testing of the any new overcurrent relays, existing CTs and the Adaptive Protection Relay was done under a Limitation of Access (LoA) safety document with the consent of the ENWL Control Engineer. Installation and testing of the 11/6.6kV A/B bus-section or T11/T12 circuit breaker tripping scheme was also performed with circuit outages and LoA with consent of ENWL Control Engineer.

APPENDIX A: ADAPTIVE PROTECTION COMMISSIONING TEST SHEETS

SITE COMMISSIONING TEST SHEET Adaptive Protection			
Prepared By - Steve Stott	Date - 22nd April 2016	Revision - Rev 04 + SJS additions	SCT Number - SCT 11kV AD PRT
Site - Denton West Primary		Circuit - Adaptive Protection T11 / T12	

Secondary Injection Tests

Test Connection	Inj (A) At AP Relay Test Block	AP Relay Display Metering Check Adaptive Protection Relay Display (kA)			
		R	Y	B	N
R-N	5.00	4.00	0.00	0.00	4.00
Y-N	5.00	0.00	4.01	0.00	4.01
B-N	5.00	0.00	0.00	4.02	4.02

Test Connection	AP Relay Phase to Phase Trip Setting (kA)	AP Relay Display Current (kA)	Relay Stable (proving 2/3 logic)?
R-N	4.50	5.50	Stable No trip
Y-N	4.50	5.50	Stable No trip
B-N	4.50	5.50	Stable No trip

Test Connection	AP Relay Phase to Phase Trip Setting (kA)	AP Relay Display Current (kA) Highest Current before Stage 1 Trip	AP Relay Display Current (kA) Current @ Stage 1 Trip Operation
R-Y	4.50	4.48	4.55
Y-B	4.50	4.37	4.50
B-R	4.50	4.45	4.54

Test Connection	AP Relay Phase to Phase Trip Setting (kA)	AP Relay Display Current (kA) to test Stage 1 & 2 Trip time	AP Relay Stage 1 trip output time (mS)	AP Relay Stage 2 trip output time (mS)
R-Y	4.50	5.38	56	358
Y-B	4.50	5.38	48	357
B-R	4.50	5.38	60	359

Test Connection	Inj (A) At Main CT Terminals	T11 Interposing CT Connected Adaptive Protection TTB (mA)				Adaptive Protection Relay Display (A)			
		R	Y	B	N	R	Y	B	E
R-N	5	2498	0	0	2498	1958	0	0	1920
Y-N	5	0	2473	0	2472	0	1966	0	1942
B-N	5	0	0	2476	2475	0	0	1965	1947
R-Y	5	2489	2486	0	0	1973	1975	0	0
R-B	5	2488	0	2486	0	1971	1972	0	0
Y-B	5	0	2498	2496	0	0	1982	1983	0

Test Connection	Inj (A) At Main CT Terminals	T11 Interposing CT Shorted Adaptive Protection TTB (mA)				Adaptive Protection Relay Display (A)			
		R	Y	B	N	R	Y	B	E
R-N	5	345	83	72	498	274	71	62	401
Y-N	5	101	334	80	53	82	267	62	410
B-N	5	99	99	323	520	81	76	257	421
R-Y	5	238	240	0	0	189	196	0	0
R-B	5	236	0	241	0	189	0	191	0
Y-B	5	0	242	242	0	0	194	196	0

Test Connection	Inj (A) At Main CT Terminals	T12 Interposing CT Connected Adaptive Protection TTB (mA)				Adaptive Protection Relay Display (A)			
		R	Y	B	N	R	Y	B	E
R-N	5	2498	0	0	2500	1975	0	0	1976
Y-N	5	0	2502	0	2493	0	1992	0	1989
B-N	5	0	0	2500	2495	0	0	1991	1993
R-Y	5	2501	2501	0	0	1990	1990	0	0
R-B	5	2503	0	2502	0	1999	0	1994	0
Y-B	5	0	2500	2499	0	0	1998	1999	0

Test Connection	Inj (A) At Main CT Terminals	T12 Interposing CT Shorted Adaptive Protection TTB (mA)				Adaptive Protection Relay Display (A)			
		R	Y	B	N	R	Y	B	E
R-N	5	330	58	53	440	260	51	40	346
Y-N	5	70	321	64	451	60	257	55	361
B-N	5	69	68	320	464	59	59	252	365
R-Y	5	250	251	11	18	200	201	0	0
R-B	5	256	10	260	21	206	0	206	19
Y-B	5	10	248	249	7	0	191	201	0

Scheme Logic Test

Plant Status	Logic Matrix @ Fault I>3 Pickup								
T11 Open	0	1	0	0	0	0	0	0	0
T11 Closed	1	0	1	1	1	1	1	1	1
T12 Open	0	0	1	0	0	0	0	0	0
T12 Closed	1	1	0	1	1	1	1	1	1
A-B Open	0	0	0	1	0	0	0	0	0
A-B Closed	1	1	1	0	1	1	1	1	1
Local Enable	1	1	1	1	0	1	1	1	1
Local Disable	0	0	0	0	1	0	0	0	0
TC Enable	1	1	1	1	1	0	1	1	1
FLAT Enable	0	0	0	0	0	0	1	0	0
Trip Supply	1	1	1	1	1	1	1	0	1
Interlock Supply	1	1	1	1	1	1	1	1	0
	Scheme Operates	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked

Plant Status	Logic Matrix @ Fault I>2 Pickup						
T11 Open	0	0	0	0	0	0	0
T11 Closed	0	1	1	0	1	0	0
T12 Open	0	0	0	0	0	0	0
T12 Closed	1	0	1	0	0	1	0
A-B Open	0	0	0	0	0	0	0
A-B Closed	1	1	0	1	0	0	0
Local Enable	1	1	1	1	1	1	1
Local Disable	0	0	0	0	0	0	0
TC Enable	1	1	1	1	1	1	1
FLAT Enable	0	0	0	0	0	0	0
Trip Supply	1	1	1	1	1	1	1
Interlock Supply	1	1	1	1	1	1	1
	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked	Scheme Blocked

Scheme Timing Test

	Output Relay (mS)	Prima Relay (mS)	CB Opening (mS)	Total Time (mS)
Stage 1 Trip Time	33	23	55	111
Stage 2 Trip Time	306	21	54	381

NOTE I> performed at 6.725A injected (5.38kA displayed) approx 38% more than min op current for trip. Stage 2 trip links are removed. CN applied.

Tests Carried Out By - S. Stott	Date - 22nd April 2016
ENW	Date - 22/04/2016