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I_S-limiter Installation and Specifications Report

30 September 2016

RESPOND

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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Paul Marshall (Reviewer)	Innovation Project Delivery Manager	28/09/16
Paul Turner (Approver)	Innovation Delivery Manager	 29/09/16

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 the I_S-limiter by September 2016

This report describes the methodology for the installation and commissioning of the I_S-limiters and their associated circuit breakers.

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 Is-limiter technology which is required on site for this approach to work. The scope of the work is to prove that the Is-limiter technology can communicate correctly with the SCADA system (telecontrol, CRMS, NMS and the FLAT tool). In addition the use of a conventional numeric overcurrent relay on the Is-limiter series CB is designed to confirm the maximum operating time of the Is-limiter. This relay is set to the same current value as the Is-limiter trip threshold and has a trip time of 0 seconds. In reality the relay will take circa 40 milliseconds to initiate a trip once it detects a fault of sufficient magnitude to operate the Is-limiter thus validating the maximum trip time.

3 RESPOND I_S-LIMITER 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 use 6.6kV rather than the more usual (in GB DNOs) 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 A

This type of installation (Broadheath primary substation) used an I_S-limiter in series with the 11kV output of a 33/11kV primary transformer. The I_S-limiter was connected in series with the T13 11kV Transformer cable box and the T13 11kV switchgear cable box. The I_S-limiter was fitted into one of two associated containers. The I_S-limiter container also housed the I_S-limiter series circuit breaker (CB) which was connected to both the I_S-limiter and the T13 11kV switchgear cable box. The I_S-limiter series CB was installed in order to disconnect all three 11kV phases of the T13 transformer in the event that any of the I_S-limiter fuses operate to prevent single or dual phasing from occurring.

In order to reduce the risk of loss of supply to customers following an I_S-limiter trip a By-pass CB was connected across the I_S-limiter/ I_S-limiter series CB combination. The By-pass CB was housed in its own separate container and consisted of one CB which could be opened and closed by telecontrol (SCADA) and one which could not in series with each another. The reason for the second non telecontrol operated CB was that its cable box was capable of being connected to the number and size 11kV cables from T13. If the I_S-limiter operates then one or more of its fuses will blow and then within 100mS the I_S-limiter series CB will trip disconnecting all 3 11kV phases of T13 from the 11kV system. Once all the various automatic telecontrol fault restoration switching is complete and the 11kV system fault is disconnected from the system the control engineer can close the I_S-limiter By-pass CB to allow T13 to contribute power to the system and increase the security of supply to customers. Once the I_S-limiter fuse(s) have been replaced and the I_S-limiter restored to service position then the I_S-limiter series CB can be closed by telecontrol and the I_S-limiter By-pass CB opened. This causes all power from T13 to flow via the I_S-limiter so that it is ready to interrupt any further fault current contribution on the 11kV system.

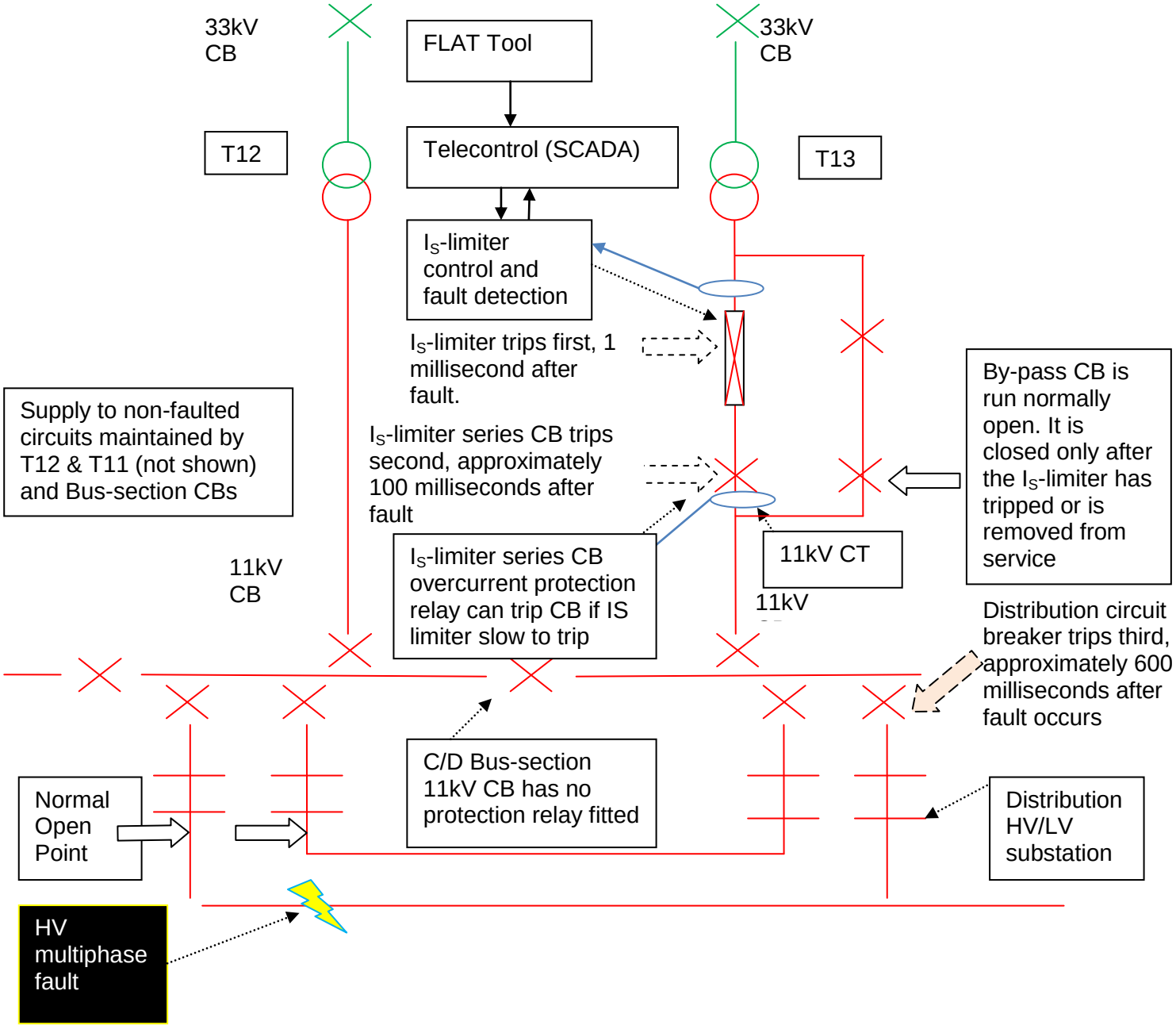
The I_S-limiter series CB is normally tripped by the I_S-limiter or via telecontrol. It also has its own CTs and protection relay. This relay trips the I_S-limiter Series CB if it sees a phase to phase event of 3500A (earth fault trip is not enabled). It performs this trip without any additional intentional time delay, which in reality means it will issue a trip command circa 40mS. The reason for this setting is to prove that the I_S-limiter detects, operates its fuses and clears the fault in less than the circa 40mS of the protection relay. If the protection relay were to issue a trip during any 11kV system fault then it would indicate a failure of the I_S-limiter.

The I_S-limiter is set to operate at a current value of 3500A coupled with a rate of change of current setting. The value of 3500A was chosen so that the likelihood of the I_S-limiter tripping any of its fuses for an earth-fault between it and T13 was negligible. Even if a parallel is made with another primary substation without opening transformers or bus section 11kV CBs then earth fault level should not exceed 3000A. A value of 3500A is only around 2/3 of the maximum 3 phase fault and ¾ of the maximum 2 phase fault contribution from T13 to a downstream fault. Having a value of 3500A therefore increases the likelihood of a successful operation during the trial period.

Site list

Broadheath (South West Greater Manchester)

Figure 1: 'Type A' I_S-limiter Installation



3.2 Type B

This type of installation (Bamber Bridge primary substation) used an I_S-limiter in parallel with a normally open 'A/B Bus-section' 11kV CB. The I_S-limiter was connected in series with two existing and unused 11kV CB, one on the end of section 'A' and the other at the end of section 'B' 11kV switchboards. This arrangement effectively shorts out the 'A/B Bus-section' 11kV CB hence when the I_S-limiter is in service the 'A/B Bus-section' 11kV CB is made open via telecontrol to force any fault current to pass from either section via the I_S-limiter.

The I_S-limiter was fitted into one container as there is no need for an I_S-limiter By-pass CB as the legacy 'A/B Bus-section' 11kV CB performs this function should the I_S-limiter operate or be taken out of service. The I_S-limiter container also housed the I_S-limiter series circuit breaker (CB) which was connected to both the I_S-limiter and the section 'B' I_S-limiter CB 11kV switchgear cable box. The I_S-limiter series CB was installed in order to disconnect all three 11kV phases of the two sections from one another (sections 'A' & 'B') in the event that any of the I_S-limiter fuses operate. This was done to prevent single or dual phasing from occurring.

In order to reduce the risk of loss of supply to customers following an I_S-limiter trip legacy 'A/B Bus-section' 11kV CB would be closed by telecontrol. If the I_S-limiter operates then one or more of its fuses will blow and then within 100mS the I_S-limiter series CB will trip disconnecting all 3 11kV phases of section 'A' from section 'B'. Once all the various automatic telecontrol fault restoration switching is complete and the 11kV system fault is disconnected from the system the control engineer can close the 'A/B Bus-section' 11kV CB to allow T11 and T12 to contribute power to the whole system fed from sections 'A' and 'B' thus leading to an increase in the security of supply to customers. Once the I_S-limiter fuse(s) have been replaced and the I_S-limiter restored to service position then the I_S-limiter series CB can be closed by telecontrol and the 'A/B Bus-section' 11kV CB opened. This causes all power flows between sections 'A' and 'B' to flow via the I_S-limiter so that it is ready to interrupt any further fault current contribution on the 11kV system.

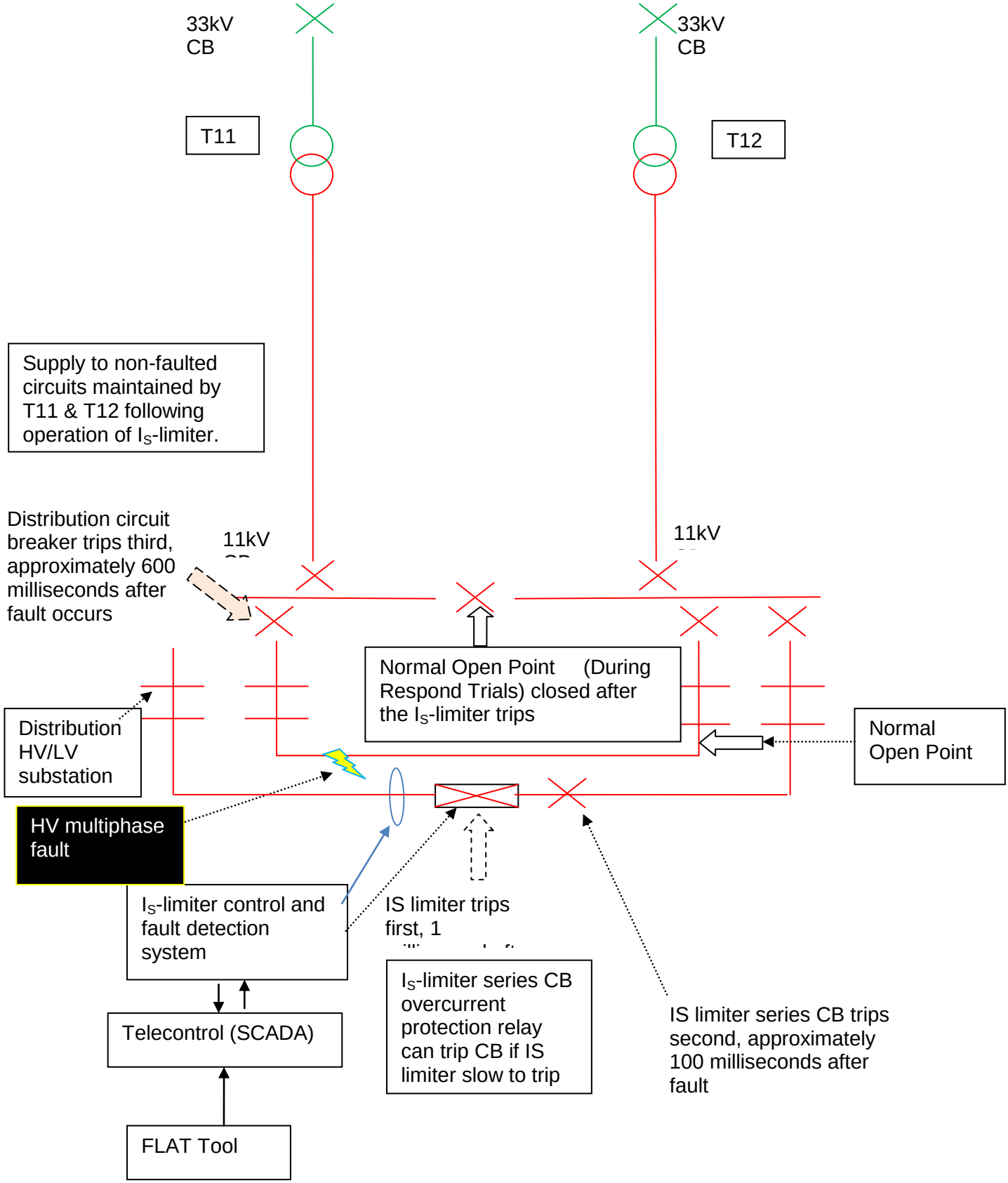
The I_S-limiter series CB is normally tripped by the I_S-limiter or via telecontrol. It also has its own CTs and protection relay. This relay trips the I_S-limiter Series CB if it sees a phase to phase event of 3500A (earth fault trip is not enabled). It performs this trip without any additional intentional time delay, which in reality means it will issue a trip command circa 40mS. The reason for this setting is to prove that the I_S-limiter detects, operates its fuses and clears the fault in less than the circa 40mS of the protection relay. If the protection relay were to issue a trip during any 11kV system fault then it would indicate a failure of the I_S-limiter.

The I_S-limiter is set to operate at a current value of 3500A coupled with a rate of change of current setting. The value of 3500A was chosen so that the likelihood of the I_S-limiter tripping any of its fuses for an earth-fault (only) was negligible. A value of 3500A is only around 2/3 of the maximum 3 phase fault and ¾ of the maximum 2 phase fault contribution which increases the likelihood of a successful operation during the trial period.

Site list

Bamber Bridge (South East Preston)

Figure 1: 'Type B' I_S-limiter installation



3.3 Type C

This type of installation used the fault detection and trip decision making equipment found in a conventional I_S-limiter but without the installation of primary equipment to break fault current. Retrofit slip-over current transformers (CT) were fitted on the outside of existing 11kV and 33kV cables. This was done to gain data on how often I_S-limiters would operate on a DNO network without incurring the costs of fitting them to numerous sites. These sites are referred to as Is-sensing sites.

Site list

Athletic St 33kV (East Lancashire)

Wigan BSP (North West Greater Manchester)

Longridge (East of Preston)

Hareholme (East of Preston)

Nelson (East Lancashire)

Photograph of Wigan Is-sensing equipment

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

HV pressure test sets

ABB propriety I_S-limiter test equipment

5 COMMISSIONING STRATEGY

Network outages were required for the commissioning of the Is-limiters, as primary conductors needed to be connected to the I_S-limiters.

COMMISSIONING LESSONS LEARNT

- The ABB I_S-limiters were tested in the ABB factory however it was found that commissioning on site was still required in terms of I_S-limiter system functionality and switchgear high voltage insulation and continuity checks on site following transportation and installation.
- The ground-works at Broadheath proved particularly challenging due to legacy buried cables and records. This lengthened the installation phase and added to costs.
- Consideration to the trialling of screw piles may have speeded up the civil engineering during the I_S-limiter container foundation building stage of the installation at Broadheath.

6 APPENDIX A – TYPE 1 COMMISSIONING REPORT

	ABB AG Calor Emag Medium Voltage Products	DEABB/PPMV
	Integrated Managementsystem	Page 1 to 3
	Testing and Commissioning – Checklist I_S-Limiter panel, type: ZS-truck	Subject: Q Type no.: AA 1VBA500041P0202

Order no. : *15/243103305/2* Date : *13.04.2013*
Customer : *ENWL GB*
Place of Installation : *Bamber Bridge Substation* Inspector : *R. Zaayenga*

Item.	Steps of Testing	N.A.	Checked yes	Checked no
1	**I_S-Limiter cubicle**			
1.1	Integration of cubicle / build-in direction of CT´s (P1-P2)		✓	
1.2	Main grounding bar between I_S-Limiter cubicle and switchgear / main point of ground			✓
1.3	Function of shutter		✓	
1.4	Sliding contact of I_S-Limiter truck grounding greased		✓	
1.5	Labels (Busbar/Cable)		✓	
1.6	Ext. wires and internal wires/tripping lines laid separate		✓	
2	**I_S-Limiter truck**			
2.1	Insertability of the I_S-Limiter inserts		✓	
2.2	Correctness of I_S-Limiter inserts		✓	
2.3	Spring pressure of telescope contact		✓	
2.4	Grounding bar and contact-system greased		✓	
2.5	Information- and type-labels		✓	
2.6	Movability of I_S-Limiter truck		✓	
3	**Additional current transformer**			
3.1	Mounting place	✓		
3.2	Build-in direction (P1-P2)	✓		
3.3	Allocation of CT-cores	✓		
3.4	Transmission ratio (acc. type-labels)	✓		
3.5	Performance data (acc. type-labels)	✓		
3.6	Spring contact	✓		
3.7	Wiring	✓		
3.8	Single sided grounding of all cable shields	✓		
4	**Electrical testing**			
4.1	Power supply voltages		✓	
4.2	Truck interlocking		✓	
4.3	Position indicator		✓	
4.4	Heater		✓	
4.5	I_S-limiter		✓	
4.6	Compartment lighting	✓		
4.7	Fan	✓		
4.8	Contacts of paneldoor		✓	
4.9	Interlocking of paneldoor		✓	

Create /Modification:	Dept.:	Name:	Sign.	Checked:	Dept.:	Name:	Sign.	Release:	Dept.:	Name:	Sign.
10.02.09 / Index 01	BT	Kierkoff		11.02.09	BT	Grote		11.02.09	B	Brandt	

File: Checkliste_243103305_2_2016_04_14

ABB	ABB AG Calor Emag Medium Voltage Products	DEABB/PPMV
	Integrated Managementsystem	Page 2 to 3
	Testing and Commissioning – Checklist I_S-Limiter panel, type: ZS-truck	Subject: Q Type: AA / no.: 1VBA500041P0202

Order no. : *15/243103305/2* Date : *13.04.2013*
Customer : *ENWL GB*
Place of Installation : *Bamber Bridge Substation* Inspector : *R. Zaayenga*

Item	Steps of Testing	N.A.	Checked yes	Checked no
5	**I_S-Limiter tripping unit**			
5.1	Testing based on the I_S-Limiter test certificate		✓	
5.2	Alarms (potential-free contacts)		✓	
5.3	Interlocking/release of the circuitbreaker		✓	
5.4	Inspection plate fitted		✓	
6	**Final works**			
6.1	CT terminals in service position		✓	
6.2	Tools, measuring lines, test inserts, et cetera removed		✓	
6.3	Cleanness of the units		✓	
7	**Miscellaneous**			
1.2	*Main ground just temporary at the moment*			
Remarks and Details				

The correctness of item 6.1 and 6.2 has been checked by the customer!!!

Place: *Preston* Date: *13.04.2016* Sign: (customer)

Place: *Preston* Date: *13.04.2016* Sign: (ABB) *R. Zaayenga*

Create /Modification : Index 01 Date of Release : 11.02.2009
File: Checkliste_243103305_2_2016_04_14

ABB AG — Oberhausener Straße 33, 40472 Ratingen

TEST CERTIFICATE FOR IS-LIMITER - TRIPPING EQUIPMENT

Customer : *ENWL GB*
Place of installation : *Bamber Bridge Substation*

Tripping equipment type : *QR3S-031 D-F* Serial no. *15/243103305/2*
Test equipment type : *QT2c, No.24*

1. Measurement of auxiliary voltages

Supply voltage 1: *100* V AC
Supply voltage 2: *241.2* V AC

Please underline the applicable test voltage.

D.C. voltages:

	U 15-7 [V]	U 14-7 [V]	U 15-14 [V]
L1	*155.0*	*142.1*	*12.66*
L2	*155.6*	*142.6*	*12.63*
L3	*155.8*	*142.6*	*12.80*

2. Inspection of the voltage monitor

Operation of the indicator relay „Is-limiter not ready"
(Connect Socket 7 with Socket 14)

L1	✓
L2	✓
L3	✓

3. Operational testing

x = Tripping o = No tripping

Operated push button b3	1	2	3	4	5	6	7	8	1	2	1
Operated in addition	-	-	-	-	-	-	-	-	b5	b6	BL
Required result	x	x	x	x	o	o	o	o	o	o	o
Phase L1	*x*	*x*	*x*	*x*	*o*	*o*	*o*	*o*	*o*	*o*	*o*
Phase L2	*x*	*x*	*x*	*x*	*o*	*o*	*o*	*o*	*o*	*o*	*o*
Phase L3	*x*	*x*	*x*	*x*	*o*	*o*	*o*	*o*	*o*	*o*	*o*

Check of bursting circuit by means of testing Cartridge (3 per phase)
Phase L1: ✓✓✓✓
Phase L2: ✓✓✓✓
Phase L3: ✓✓✓✓

BL = I_s-limiter blocked by energizing relay –K203

4. Operating values of measuring element 1

Minimum voltage at which tripping happened:
(Measuring instrument indicates in the 15 V range)

	U [V]
L1	*11.30*
L2	*11.33*
L3	*11.30*

5. Operating values of measuring element 2

Minimum voltage at which no tripping happened:
(Measuring instrument indicates in the 15 V range)

	U [V]
L1	*12.03*
L2	*12.02*
L3	*12.02*

6. Checking the measuring circuitry

Measured voltages in [V] (Measuring range 4 V)

Button at b3	1	2	3	4	5	6	7	8			
Phase L1	*2.695*	*2.677*	*1,358*	*1,361*	/	/	*1.694*	*1.703*			
Phase L2	*2.701*	*2.702*	*1,339*	*1,351*	/	/	*1.695*	*1.684*			
Phase L3	*2.688*	*2.689*	*1,346*	*1,350*	/	/	*1.690*	*1.687*			

Remarks:

Intertrip and interlocking to CB successfully tested to panel =A01:
Alarms tested until terminals marshalling panel, All current terminals in service position

Place: *Preston* Date: *13.04.2016* Inspector: *R. Zaaayenga*

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