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RESPOND POST FAULT ANALYSIS

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WSP | Parsons Brinckerhoff
Manchester Technology Centre
Oxford Road, Manchester M1 7ED

Tel: +44 (0) 161 200 5000
Fax: +44 (0) 161 200 5001
www.wsp-pb.com

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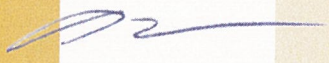
Signature				
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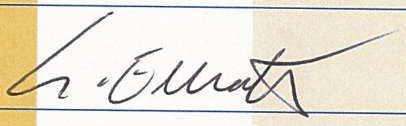
Signature				
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PRODUCTION TEAM

CLIENT

Future Networks Engineer	Kieran Bailey	Kieran Bailey Digitally signed by Kieran Bailey DN: cn=Kieran Bailey, c=GB - UNITED KINGDOM, o=None, E=kieran.bailey@email.co.uk
Future Networks Engineer	Paul Turner	

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Project Manager	Gillian Williamson
Technical Specialist	Peter Watson

TABLE OF CONTENTS

TABLES

FIGURES

1 INTRODUCTION

Electricity North West's Respond, second tier Low Carbon Network funded project, is investigating active fault level management techniques as a cost beneficial alternative to traditional reinforcement of network assets.

Three fault level mitigation techniques are being trialled as part of the Respond project. Performance of these techniques is assessed by examining the systems' behaviour in response to a fault. This report presents the analysis of a fault event occurring during the Respond trial in accordance with Successful Delivery Review Criteria, SDRC 9.3.3, as shown below.

CRITERIA	EVIDENCE
3. Implement monitoring and post fault analysis procedures in Trial period	3. Publish on Respond website a summary of each fault event three months after each event, with the expectation that a minimum of 18 faults will be reported on

2 EVENT DETAILS

Substation	Blackbull Primary
Fault Mitigation Technique	Adaptive Protection
Voltage	6.6 kV
Date/Time	3 April 2017 / 16.00.47
Faulted Circuit	Lansdown Hill S 6.6 kV circuit
Fault Location	The fault was located on the spur to Sandyforth Ln Borehole. The fault was cleared by a mid-point circuit breaker at Lansdown Hill S/S:- The tripping CB was the Newsham Ln/Wychnor Rd OD 6.6 kV CB on the Lansdown Hill Sth 6.6 kV cct out of Blackbull Pry.

3 SITE AND INSTALLATION INFORMATION

3.1 NETWORK DATA

The pre-fault Blackbull Primary substation configuration is shown in Figure 3.1. Note: The feeders to the Royal Preston Hospital substation form a closed ring.

For the Respond trials, the 6.6 kV transformer incomer CTs are connected in parallel. The phase current input to the Adaptive Protection (AP) high-set instantaneous overcurrent relay (50) receives the sum of the current in each transformer incomer. Operation of the Adaptive Protection is fed into the bus section directional overcurrent relay (67-50) which is part of the existing busbar protection blocking scheme. On receipt of a trip signal from the AP protection, the 67-50 initiates tripping of the 6.6 kV bus section circuit breaker, and depending on whether the fault is detected in the forward or reverse direction, also initiates tripping of the Royal Preston Hospital feeder circuit breaker connected to the section of bus bar associated with the fault. Opening the connections between the two 6.6 kV transformer incomers increases the impedance to the fault and therefore reduces the initial fault current.

Pre-fault loading information is shown in Table 3-1.

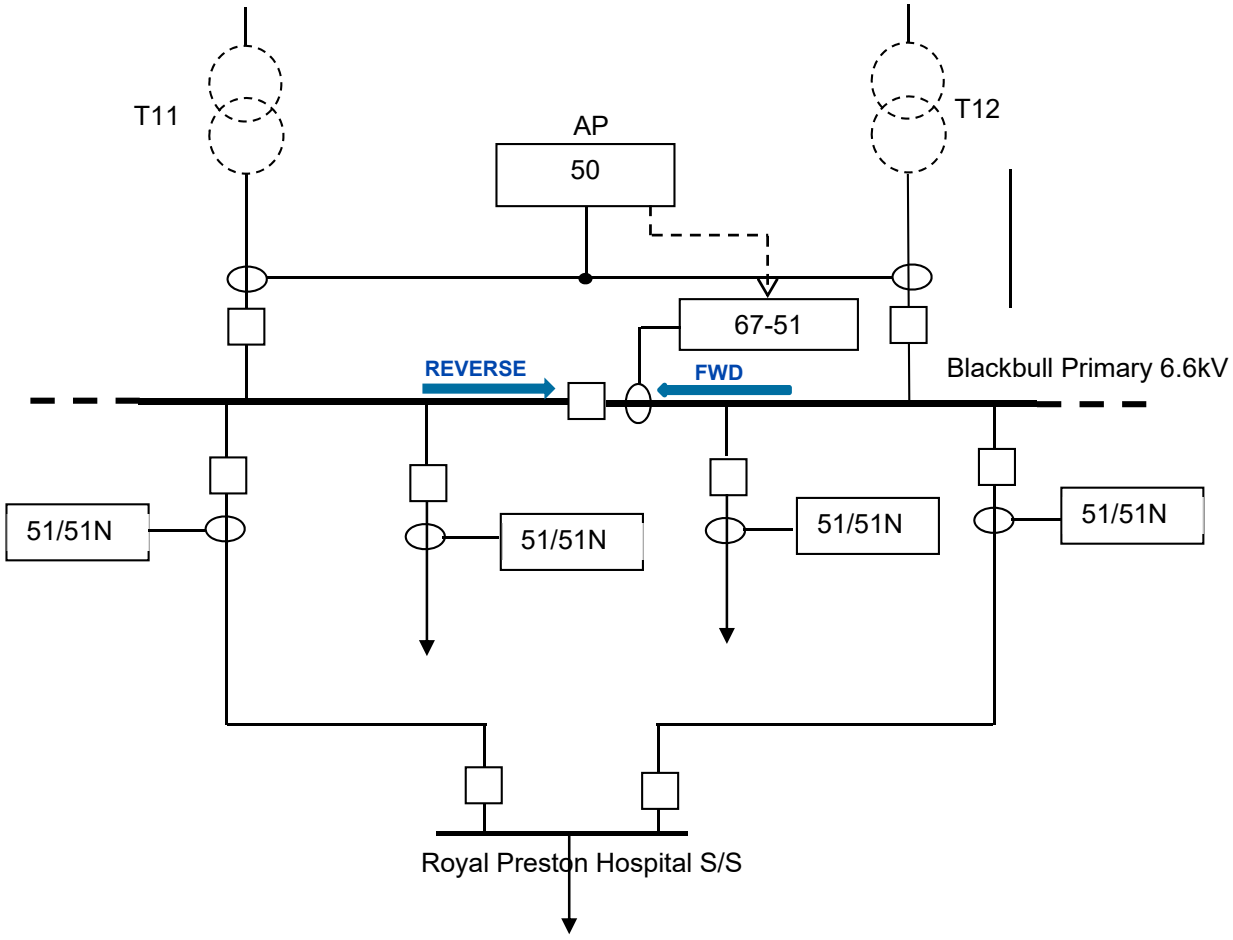

Figure 3-1: Blackbull Primary Network

Table 3-1: Pre-fault Load Conditions

Pre-fault load data (1/2hour) at 15:30 Hrs on 3 April 2017	
Blackbull Primary	683 A
Lansdown Hill Sth. Feeder	71 A

3.2 PROTECTION DATA

The Adaptive Protection has the facility to be remotely switched in and out of service, however in this case it is permanently enabled.

Table 3-2: Blackbull Primary Adaptive Protection Settings

CT	4000/5 (2000/5 into 5/2.5 interposing CT)
Relay	MiCOM P40 Agile P145
I>1 Function	Disabled
I>2 Function	Disabled
I>3 Status	Enabled
I>3 Direction	Non-Directional
I>3 Current Set	4520A
I>3 Time Delay	0 s (The manufacturer's declared accuracy for definite time (DT) operation is ±2% or 50ms, whichever is greater.)
I>4 Status	Disabled
Comment	The setting of 4520 A is well below the short circuit capability of the Blackbull Primary 6.6 kV switchgear (20 kA), but this value is selected for these trials to ensure operation for 6.6 kV phase faults.

Table 3-3: Lansdown Hill Sth 6.6 kV Feeder at Blackbull Primary Protection Settings

CT	600/5
Relay	ARGUS 1 (2 Phase Overcurrent and Earth Fault)
I>	0.85 x In (510 A)
t>	0.4, Standard Inverse
Io>	0.15 x In (90 A)
to>	0.4, Standard Inverse

3.3 EVENT INFORMATION

3.3.1 Fault Level Calculations

The calculated values of fault current from the Fault Level Assessment Tool (FLAT) and Dinis are as shown in Table 3-4.

Table 3-4: Fault Current Values

Schneider NMS FLAT Fault Current Values at fault location	
Three Phase Fault Level	7.297 kA
L-L Fault Level	6.320 kA
L-L-G Fault Level	6.613 kA
Dinis Fault Current Values at fault location	
Three Phase Fault Level	Red = 6.312 kA /308° Yellow = 6.312 kA /188° Blue = 6.312 kA /68°
L-L Fault Level	Red = 0 kA /0° Yellow = 5.67 kA /218° Blue = 5.67 kA /38° Residual = Not listed
L-L-G Fault Level	Red = 0 kA /0° Yellow = 5.98 kA /214° Blue = 5.373 kA /43° Residual = Not listed

3.3.2 Recorded Fault Current

The Adaptive Protection relay event recorder, recorded fault currents of 1059 A, 4730 A and 4111 A in the red, yellow and blue phases respectively together with a measured residual current of 37.24 A. and derived residual current of 71.12 A.

Significant current was recorded in the yellow and blue phases together with negligible residual current. This suggests a phase to phase fault. The relatively small current in the red phase compared to the yellow and blue phases is assumed to be largely attributable to the standing load.

Table 3-5 lists the AP recorded currents and the calculated fault currents.

Table 3-5: Comparison with Recorded Currents

Phase	Adaptive Protection Relay Recorder Fault Current	Schneider NMS FLAT-Calculated Three Phase Fault Level (at fault location)	DINIS Calculated Three Phase Fault Level (at fault location)
Red	1059 A	0 A	0 A (0°)
Yellow	4730 A	6320 A	5670 A (218°)
Blue	4111 A	6320 A	5670 A (38°)
Residual	37.24 A (measured) 71.12 (derived)	-	-

As shown in Table 3-5, although the fault currents recorded in the Adaptive Protection relay are less than the calculated FLAT and DINIS phase to phase fault currents, they do show some correlation, particularly considering that the modelling of the upstream system in both cases is based on an assumption.

4 EVENT TIME LINE

4.1 EVENT TIMES FROM CRMS

The events recorded at the CRMS are shown in Table 4-1

Table 4-1: CRMS Event Timings

Time	Event
16:00:47	Blackbull Bus Section Adaptive Protection (AP) Stage 1 operated
16:00:47	Blackbull Lansdown Hill S 6.6 kV Feeder Amps High Alarm
16:00:47	Blackbull T11 6.6 kV VT – kVolts Low Alarm
16.00.47	Blackbull T11 6.6 kV Amps High Alarm
16:00:47	Blackbull T12 6.6 kV VT – kVolts Low Alarm
16:00:47	Blackbull Bus section CB opened
16:00:47	Blackbull Royal Preston Hospital 6.6 kV Feeder CB opened
16:00.48	Blackbull T12 6.6 kV VT – kVolts Normal
16:00.48	Blackbull Lansdown Hill S 6.6 kV Feeder Amps Normal
16:00.48	Blackbull T11 6.6 kV VT – kVolts Normal
16:00.48	Blackbull T11 6.6 kV – Amps Normal
16.00.49	Blackbull Bus Section Adaptive Protection (AP) Stage 1 reset
16.00.55	Blackbull Automation Active Alarm
16.01.20	Blackbull Lansdown Hill S 6.6 kV Feeder Earth Fault Alarm
16.01.20	Blackbull Lansdown Hill S 6.6 kV Feeder Amps High Alarm
16.01.20	Blackbull T11 6.6 kV VT – kVolts Low Alarm
16.01.20	Blackbull T11 6.6 kV – Amps High Alarm
16.01.20	Blackbull 6.6 kV Neutral Current Alarm
16.01.21	Blackbull Lansdown Hill S 6.6 kV Feeder Earth Fault Alarm reset
16.01.21	Blackbull 6.6 kV Neutral Current Alarm reset
16.01.21	Blackbull T11 6.6 kV – Amps Normal
16.01.22	Blackbull Lansdown Hill S 6.6 kV Feeder Amps Normal
16.01.22	Blackbull T11 6.6 kV VT – kVolts Normal
16.01.27	Blackbull Automation Active Alarm
16.02.19	Blackbull Automation Active Alarm
16.03.28	Blackbull ARS Sequence Completed

4.2 EVENTS FROM LANSDOWN HILL SOUTH 6.6.KV FEEDER PROTECTION RELAY

The events recorded on the Lansdown Hill South 6.6 kV feeder protection are shown in Table 4-2 below.

Table 4-2: Lansdown Hill Sth Feeder Protection Relay Event Timings

Time*	Event
16:41:56.220	Raised General starter
16:41:56.220	Raised C-starter
16:41:56.220	Raised Output7
16:41:56.385	Raised A-starter
16:41:57.100	Cleared General starter
16:41:57.100	Cleared A-starter
16:41:57.100	Cleared C-starter
16:41:57.100	Cleared Output7
16:42:29.565	Raised General starter
16:42:29.565	Raised A-starter
16:42:29.565	Raised C-starter
16:42:29.565	Raised Output7
16:42:29.570	Raised SEF/REF starter
16:42:29.570	Raised SEF/REF lowset trip
16:42:29.570	Raised E/F-general trip
16:42:29.580	Raised E-HS1 starter
16:42:29.580	Raised E-HS1 trip
16:42:29.580	Raised E/F-general trip
16:42:29.580	Raised E/F-general HS trip
16:42:29.580	Raised Output8
16:42:29.685	Raised E-starter
16:42:30.610	Cleared E-starter
16:42:30.615	Cleared SEF/REF starter
16:42:30.615	Cleared SEF/REF lowset trip
16:42:30.615	Cleared A-starter
16:42:30.615	Cleared C-starter
16:42:30.615	Cleared Output7
16:42:30.620	Cleared General starter
16:42:30.620	Cleared E-HS1 starter
16:42:30.620	Cleared Output8

* Time stamps on Lansdown Hill South Feeder Protection Event Records are 41 minutes 1 sec ahead of actual time.

No currents were recorded for this event.

4.3 DISTURBANCE RECORDS

Mismatch between disturbance recorder settings and the programmable scheme logic (PSL) within the AP relay mean that disturbance recordings were not triggered for this fault. In the disturbance recorder settings, operation of output relay R3 is set to trigger the disturbance recorder, however, output relay R3 is not assigned in the PSL. Output relay R7 is assigned to trigger the disturbance recorder in the PSL, however, operation of output relay R7 is not defined in the settings to trigger the disturbance recorder. Analogue waveforms are not available for the fault as a consequence of the disturbance recorder not triggering due to the discrepancy.

5 DISTURBANCE ANALYSIS

Based on currents recorded on the Adaptive Protection relay and on the events recorded in the Lansdown Hill South feeder protection relay and on the CRMS log, this incident started as a phase to phase fault on the Lansdown Hill South 6.6 kV feeder.

The fault current (4730 A) in the yellow phase of the Adaptive Protection relay was just above its pick-up current setting of 4520 A. The Adaptive Protection Stage 1 operated which tripped the 6.6. kV bus section circuit breaker and the Royal Preston Hospital feeder via the Bus Section Directional Overcurrent relay.

The Lansdown Hill South feeder protection relay detected the fault, but did not operate as the fault was cleared by a mid-point circuit breaker at Lansdown Hill S/S:- The tripping CB was the Newsham Ln/Wychnor Rd OD 6.6 kV CB which is fed from Blackbull Pry on the Lansdown Hill Sth 6.6 kV circuit.

The CRMS log indicates that following the tripping of the bus section and Royal Preston Hospital circuit breakers, the automation sequence was active. The mid-point circuit breaker at Lansdown Hill S/S reclosed on to the fault. This is indicated on the CRMS log by the feeder earth fault alarm and the T11 low volts and high amps. The mid-point circuit breaker at Lansdown Hill S/S tripped again and locked out.

6 CONCLUSIONS

The available information indicates that the Adaptive Protection operated correctly to trip the bus section circuit breaker and the Royal Preston Hospital Feeder circuit breaker. Opening of these circuit breakers would have reduced the fault current but the extent of the reduction cannot be quantified without a disturbance record. Further analysis is also not possible without a disturbance record.