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RESPOND POST FAULT ANALYSIS

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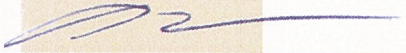
Signature				
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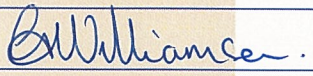
Signature				
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1 INTRODUCTION

The 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	Atherton Town Centre
Fault Mitigation Technique	Adaptive Protection
Voltage	11kV
Date/Time	29 July 2016 / 22.29.10
Faulted Circuit	Collier Brook 11kV circuit
Fault Location	The fault was located near Jose Holt Gordon PMT, 10m towards Macro Rd (rear 695) on the 11KV cable section between Manchester Rd (RR 695) S/S and Winslow Rd S/S

3 SITE AND INSTALLATION INFORMATION

3.1 NETWORK DATA

The pre-fault Atherton Town Centre network configuration is shown in Figure 3-1. For the Respond trials, the 11kV transformer incomer CTs are connected in parallel. The respective phase current input to the Adaptive Protection high-set instantaneous overcurrent relay (50) receives the sum of the current in each transformer incomer. Operation of the Adaptive Protection initiates the tripping of the11 kV bus section circuit breaker, increasing the impedance to the fault and reducing the initial fault current.

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

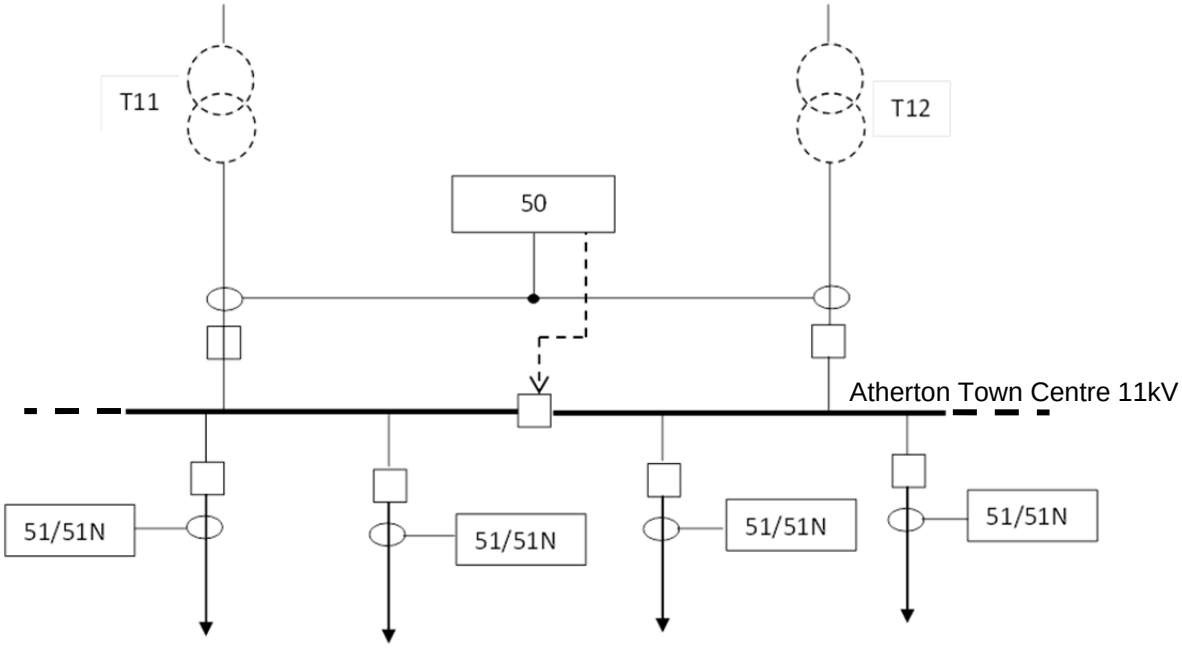

Figure 3-1: Atherton Town Centre Network

Table 3-1: Pre-fault Load Conditions

Pre-fault load data (1/2hour)	
Atherton Town Centre	647.87 A
Collier Brook Feeder	141.68 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: Atherton Town Centre Adaptive Protection Settings

CT	4000/5
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 Atherton Town Centre 11 kV switchgear (25 kA), but this value is selected for these trials to ensure operation for 11 kV phase faults.

Table 3-3: Collierbrook 11kV Feeder Protection Settings

CT	400/5
Relay	MCGG52 (2 Phase Overcurrent and Earth Fault)
I>	I.5 x In (600 A)
t>	0.35, Standard Inverse
Io>	0.2 x In (80 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 (for substations near the fault location)	
Three Phase Fault Level at:	
Atherton Town Centre Primary	7.86 kA
L-L-G Fault Level at:	
Manchester Rd (RR695)	4.57 kA
Winslow Rd	3.86 kA
Dinis Fault Current Values for fault location	
DINIS fault calculation (Only for L-L and L-L-G faults):	Red = 0 kA /0° Yellow = 4.78 kA /211° Blue = 4.099 kA /43° Residual = Not listed

3.3.2 Recorded Fault Current

The fault currents recorded by the relay in the yellow and blue phases (4627 A and 3772 A respectively), as shown in Table 3-5, show a close correlation with the DINIS phase to phase to earth fault current results, particularly considering that the modelling of the upstream system in Dinis is based on an assumption. However, it is noted that the FLAT phase to phase to earth fault current results are the same for the two phases, probably indicating an omission or error in the zero sequence parameters within the FLAT network representation.

Table 3-5: Comparison with Recorded Currents

Phase	Adaptive Protection Relay Recording	Schneider NMS FLAT-Calculated L-L-G Fault Level (at Manchester Rd S/S)	DINIS Calculated L-L-G Fault Level (at Jose Holt Gordon)
Red	700.7 A	-	0 (0°)
Yellow	4627 A	4570 A	4780 A (211°)
Blue	3772 A	4570 A	4099 A (43°)
Residual	645.3 A	-	-

4 EVENT TIME LINE

4.1 EVENT TIMES FROM CRMS

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

Table 4-1: Event Timings

Time	Event
22:39:09	Collier Brook Bag Lane Fault Passage Indicator (FPI) Operated
22:39:10	Atherton Town Centre 11 kV Feeder Earth Fault and Neutral Current Alarms
22.29.10	Bus Section Adaptive Protection (AP) Stage 1 operated
22.29.10	A-B Bus section CB opened
22.39.11	Atherton Town Centre - Collier Brook 11 kV CB opened
22.39.28	Atherton Town Centre - Collier Brook 11 kV CB auto-closed
22.39.30	Atherton Town Centre - Collier Brook 11 kV CB opened
22:39:42	Switches on Collier Brook Feeder opened by ARS
22.40.04	Atherton Town Centre - Collier Brook 11 kV CB auto-closed

4.2 DISTURBANCE RECORDS

The instantaneous and RMS disturbance records obtained from the Adaptive Protection relay are shown in Figure 4-1 and Figure 4-2 respectively.

In these figures, Output R3 is the trip signal from the Adaptive Protection to the 11 kV bus section circuit breaker and output R12 is the bus section circuit breaker “a” auxiliary contact repeat signal to telecontrol.

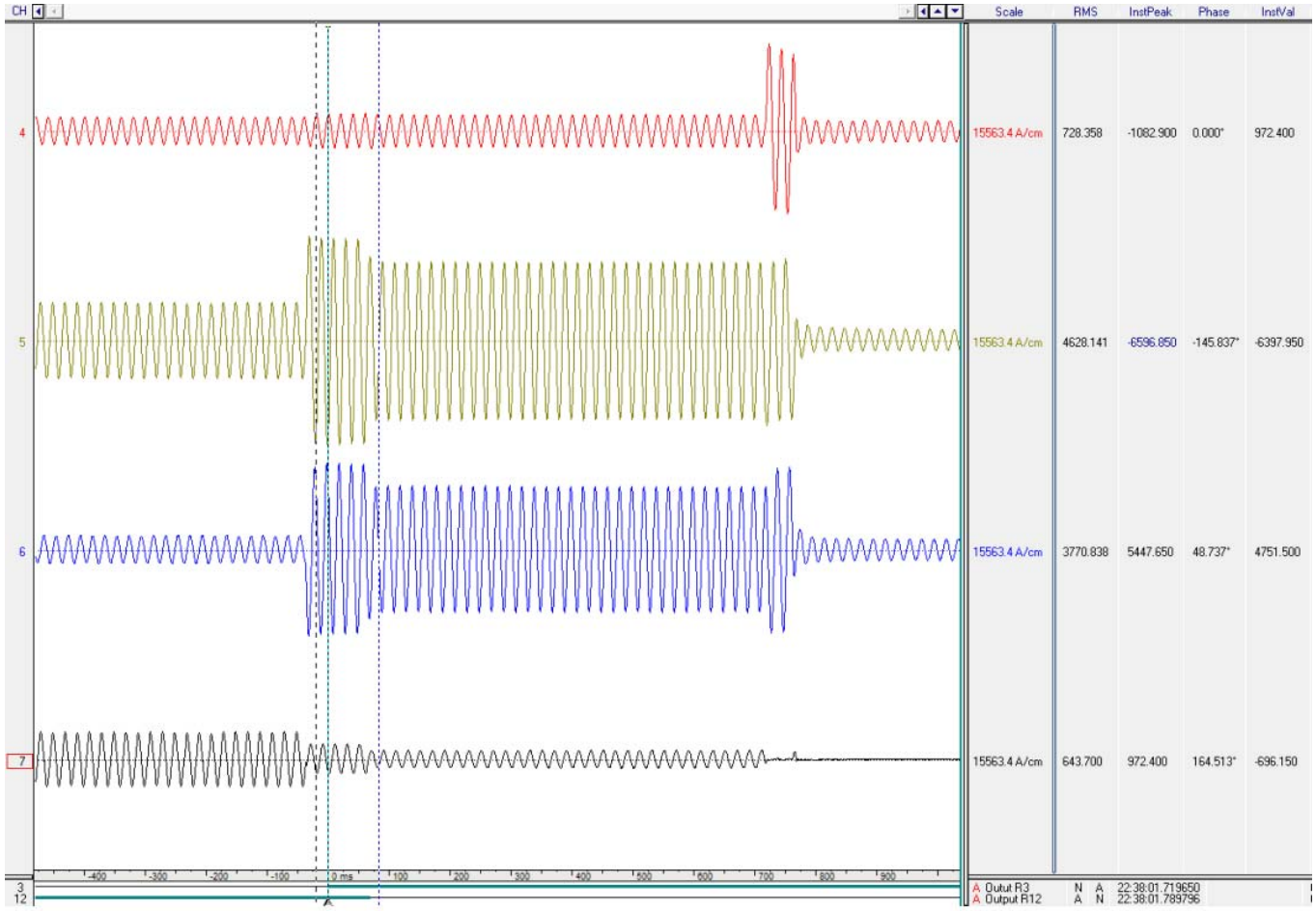

Figure 4-1: Instantaneous Adaptive Protection Relay Recordings (IA=red, IB=yellow, IC=blue and IN(residual)=black)

Cursor 1: 65 ms
Cursor 2: -36 ms
Representation: primary

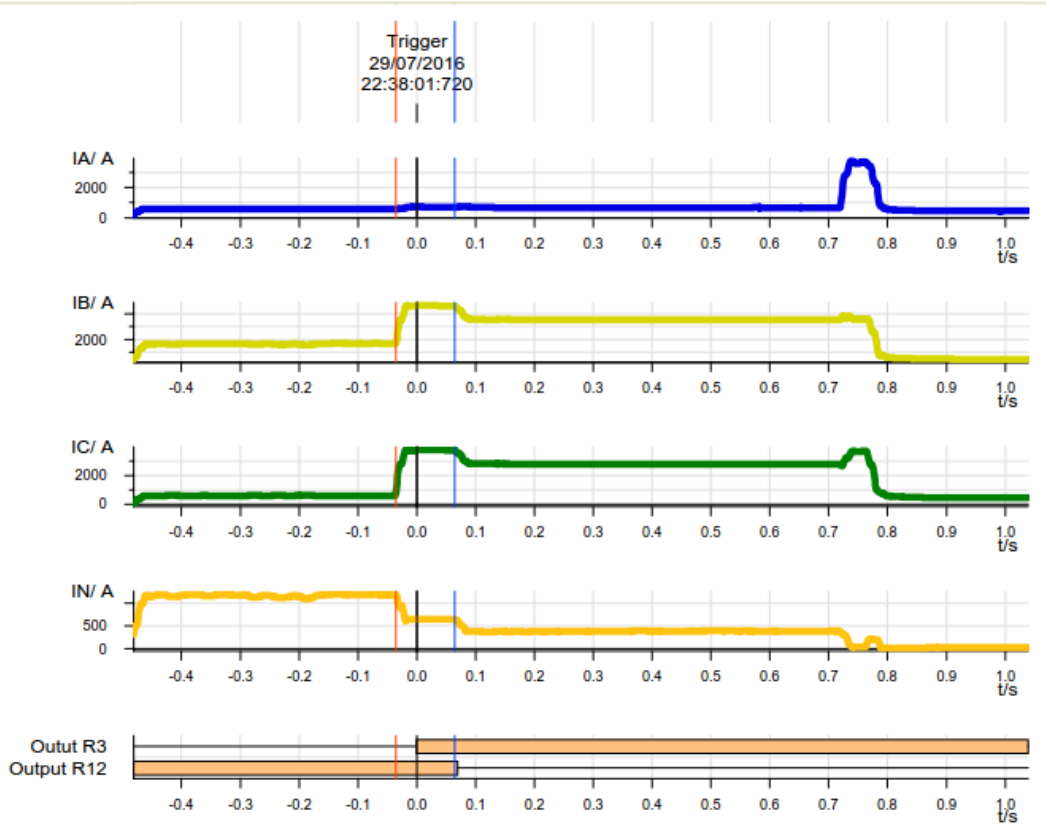

Figure 4-2: RMS Adaptive Protection Relay Recordings

5 DISTURBANCE ANALYSIS

The disturbance records show that prior to the phase to phase to earth fault which the Adaptive Protection responded to, there was a yellow phase to earth fault present. The magnitude of the earth fault current was 1161.3 A with a corresponding yellow phase fault current of 1644.5 A (inclusive of load current).

The phase to phase to earth fault with 4635.3 A and 3779.5 A in the yellow and blue phases respectively and with a 645.3 A residual fault current, occurred 35.5 ms prior to being detected by the Adaptive Protection relay. The 11 kV bus section circuit breaker tripped 64.8 ms after the trip signal from the Adaptive Protection relay was sent. The total duration of the initial phase to phase to earth fault was 100.3 ms.

After the 11 kV bus section circuit breaker tripped, the phase to phase to earth fault current reduced to 3520.8 A and 2784.3 A in the yellow and blue phases respectively and the residual fault current reduced to 391.4 A. These fault currents continued for a further 700.5 ms, developing into a three phase fault just before the feeder protection operated i.e. the fault was eventually cleared 765.3 ms after the Adaptive Protection detected the initial phase to phase to earth fault.

The residual current is seen to reduce from 645 A to 391 A (reduction of approximately 40%). This reduction in residual current reflects the dominant effect of the earthing resistors at Atherton Town Centre substation and the expected doubling of the earth resistance as the bus section is opened and the earthing resistors on each bus section are no longer in parallel.

Table 5-1 summarises the fault current durations. Table 5-2 summarises currents obtained from the disturbance records, Pre-AP Operation and Post-AP Operation currents are relative to the fault current which triggered the Adaptive Protection (AP Fault Currents). Post Fault Current is the current after operation of the feeder protection.

Table 5-1: Fault Current Durations

Phase Fault Inception	Adaptive Protection Operated	11 kV Bus Section Tripped	11 kV Feeder Protection Operated
0 ms	35.5 ms	100.3 ms	800.8 ms

Table 5-2: Disturbance Recorder Currents

	Pre-AP Operation Current	AP Fault Current	Post-AP Operation Current	Post-Fault Current
Red	580 A	715.0 A	667.3 A	450.6A
Yellow	1644.5 A	4635.3 A	3520.8 A	463.0 A
Blue	604.3 A	3779.5 A	2784.3 A	458.3 A
Residual	1161.3 A	644.1 A	391.4 A	25.14 A

6 CONCLUSIONS

The fault as recorded on the disturbance recorder integral to the Adaptive Protection relay confirms the events observed from the CRMS. The initial operation of the Fault Passage Indicator and Earth Fault and Neutral Current alarms correspond to the earth fault current seen in the disturbance records prior to the Adaptive Protection operation.

The reduction in the fault current due to the opening of the 11 kV bus section circuit breaker is clearly seen. The reduction in this case is as expected, although no generalisations can be made as the degree of the reduction will depend on the relative magnitudes for the source impedance, circuit and transformer impedances and fault resistance.

The phase to phase to earth fault was present for 35.5 ms before the Adaptive Protection was triggered. In this case the fault current was only a multiple of 1.025 times the Adaptive Protection I>3 current setting. For fault currents greater than a multiple of 2 times the current settings, the detection time should decrease.

The time between the Adaptive Protection issuing the trip signal and the 11 kV bus section circuit breaker tripping is largely dependent on the circuit breaker operating time and would not change with fault current.

Overall, the analysis has confirmed that the Adaptive Protection operated as expected and reduced the fault current to be interrupted by the feeder circuit breaker.