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RESPOND POST FAULT ANALYSIS

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Electricity North West Ltd

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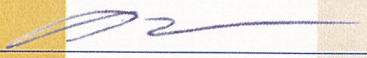
Signature				
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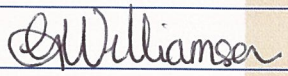
Signature				
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1 INTRODUCTION

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	11 kV
Date/Time	28 August 2016 / 19.35.15
Faulted Circuit	Thomas St/Holland St 11 kV circuit
Fault Location	The fault was located just outside Shakerley Rd substation outside No.7 Glenview Road

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 the 11 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.

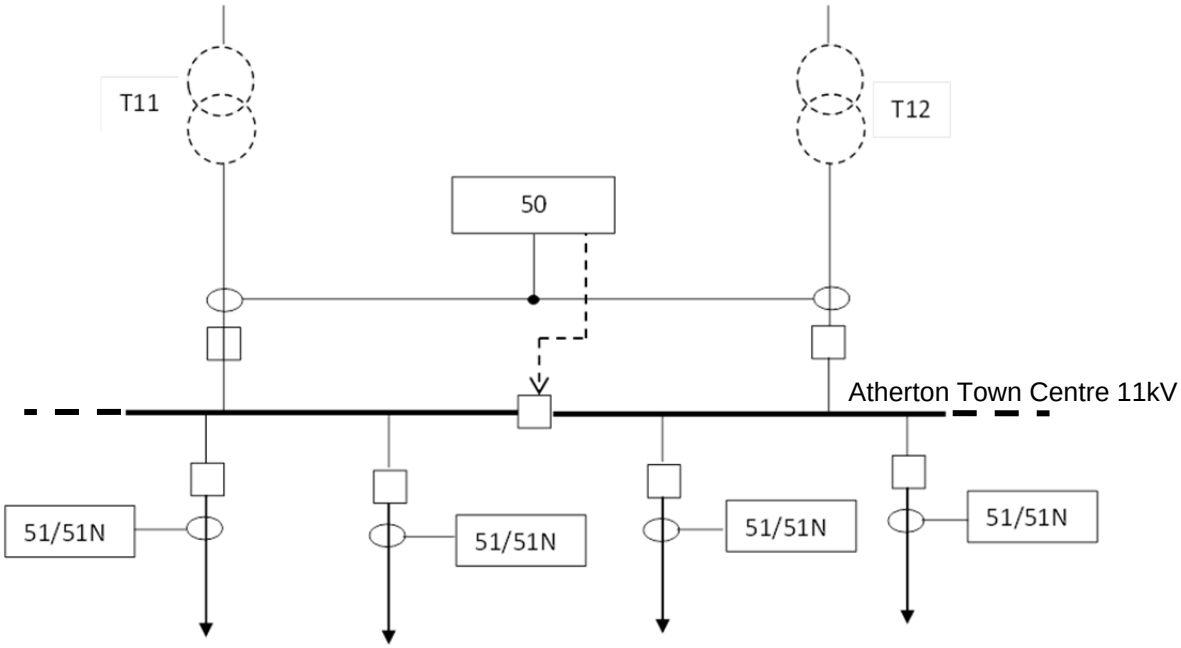

Figure 3-1: Atherton Town Centre Network

Table 3-1: Pre-fault Load Conditions

Pre-fault load data (1/2 hour)	
Atherton Town Centre	669.75 A
Thomas St/Holland St Feeder	57.64 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	4520 A
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: Thomas St/Holland St 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:	
Shakerley Rd (217296)	3.67 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 = 5.369 kA /202° Blue = 4.793 kA /35° Residual = Not listed

3.3.2 Recorded Fault Current

The fault currents recorded by the relay in the red and yellow phases (6410 A and 5190 A respectively), as shown in Table 3-5, although not very close, do show some 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, and considerably less than the measured values, 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 Shakerley Rd S/S)	DINIS Calculated L-L-G Fault Level (at Shakerley Rd S/S)
Red	6410.0 A	3167.23 A	5369 A (202°)*
Yellow	5190.0 A	3167.23 A	4793 A (35°)*
Blue	851.5 A	-	0 (0°)*
Residual	763.5 A	-	-

* DINIS Phase fault currents interposed to match the actual red–yellow phase to earth fault.

4 EVENT TIME LINE

4.1 EVENT TIMES FROM CRMS

The event recorded at the CRMS is shown in Table 4-1. It is evident that the feeder circuit breaker eventually closed within 3 minutes of its initial opening, reflecting isolation of the fault by the Automatic Restoration System (ARS) installed along the feeder.

Table 4-1: Event Timings

Time	Event
19:35:15	Thomas St/Holland St Feeder Fault Passage Indicator (FPI) Operated
19:35:15	Atherton Town Centre 11 kV Neutral Current Alarm
19:35:16	Bus Section Adaptive Protection (AP) Stage 1 operated
19:35:16	Atherton Town Centre A-B Bus section CB opened
19:35:17	Atherton Town Centre – Thomas St/Holland St 11 kV CB opened
19:37:09	Atherton Town Centre – Thomas St/Holland St 11 kV CB auto-closed
19:37:33	Atherton Town Centre - Thomas St/Holland St 11 kV CB opened
19:38:02	Atherton Town Centre - Thomas St/Holland St 11 kV CB auto-closed
22:54:20	Atherton Town Centre A-B Bus section CB 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.

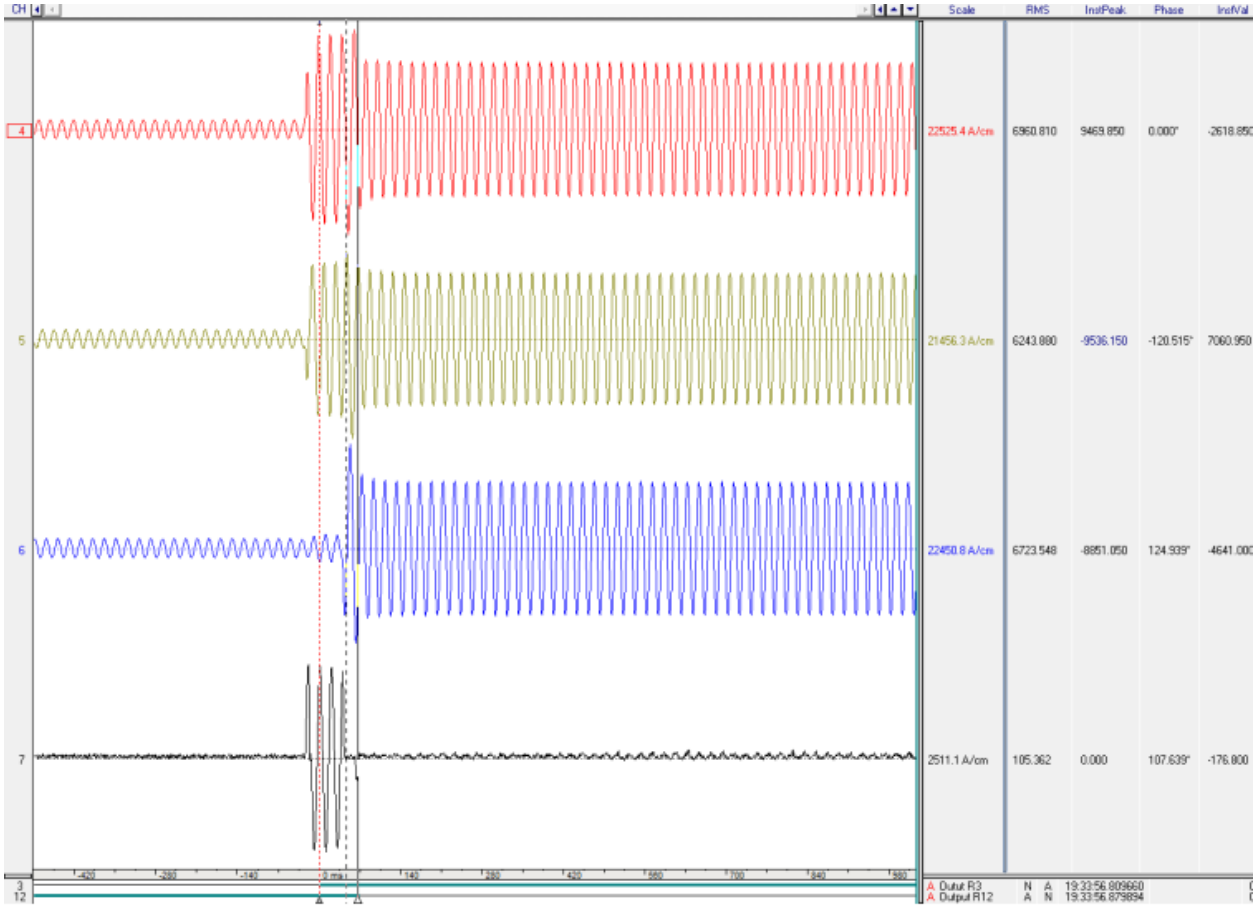

Figure 4-1: Instantaneous Adaptive Protection Relay Recordings (IA=red, IB=yellow, IC=blue and IN(residual)=black)

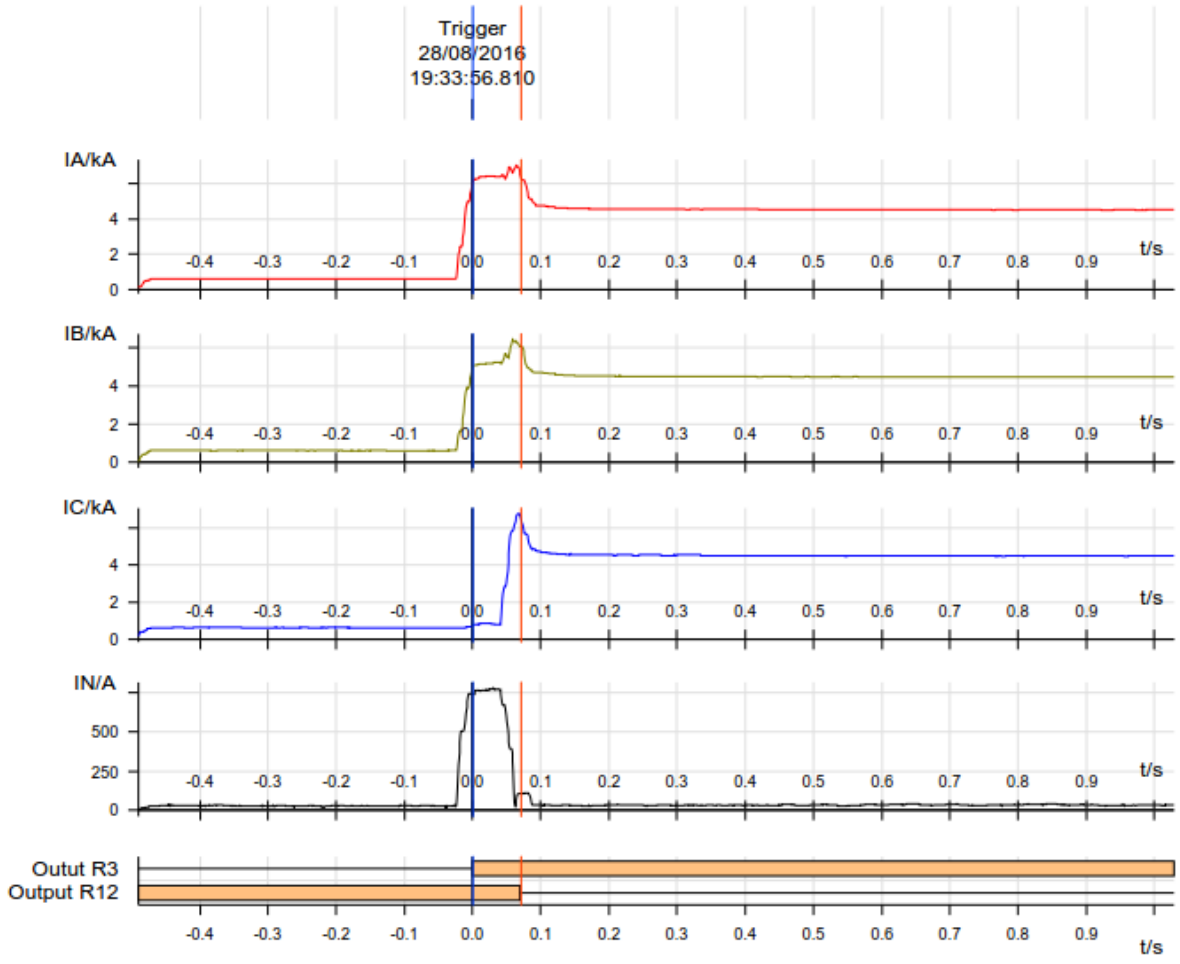

Figure 4-2: RMS Adaptive Protection Relay Recordings

5 DISTURBANCE ANALYSIS

The disturbance records show that the Adaptive Protection responded to a red phase to yellow phase to earth fault. The magnitudes of the fault currents inclusive of load current were 6418.0 A in the red phase, 5200.7 A in the yellow phase, 848.0 A in the blue phase with a residual fault current 770.1 A.

This phase to phase to earth fault occurred 23.7 ms prior to being detected by the Adaptive Protection relay. The 11 kV bus section circuit breaker tripped 69.9 ms after the trip signal from the Adaptive Protection relay was sent. The total duration of the fault up to the tripping of the 11 kV bus section circuit breaker was 93.6 ms.

The disturbance records show that the initial phase to phase to earth fault, developed into a three phase to earth fault just prior to the tripping of the Atherton Town Centre A-B bus section 11kV circuit breaker by the Adaptive Protection relay. The magnitude of the three phase currents were red phase 6681.3 A, yellow phase 6072.9 A, blue phase 6727.8 A with a residual current of 108.2 A.

After the 11 kV bus section circuit breaker tripped, the fault currents reduced to a red phase current of 4573.7 A, a yellow phase current of 4516.2 A, a blue phase current of 4540.6 A and a residual fault current of 30.42 A.

Based on the initial recorded residual fault current of 770.1 A and on the settings of the Thomas St/Holland St 11 kV feeder earth fault protection, the expected operating time of the feeder earth fault protection (excluding circuit breaker operating time) is 1.21 secs.

For the initial recorded phase fault current of 6418.0 A and based on the settings of the Thomas St/Holland St 11 kV feeder phase overcurrent protection, the expected operating time of the feeder overcurrent protection (excluding circuit breaker operating time) is 1.01 secs.

The CRMS event-log, indicates that the Thomas St/Holland St 11 kV feeder circuit breaker tripped approximately 1 second after the Atherton Town Centre A-B bus section 11kV circuit breaker opened.

The total recording time of the MiCOM P40 Agile P145 Adaptive Protection relay is set for 1.5 secs, with a pre-trigger recording time of 0.5 secs and a post trigger recording time of 1.0 secs. The opening of the Thomas St/Holland St 11 kV feeder circuit breaker therefore occurred just outside of the set disturbance recorder window and was not captured. In order to capture the opening of the feeder circuit breaker, it is recommended that the total recording time is increased to 2.0 secs with the same pre-trigger recording time of 0.5 secs. The required relay setting parameters are as follows:

Duration = 2.0 secs

Trigger Position = 25 (%)

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-Phase-Earth Fault Inception	Adaptive Protection Operated	11 kV Bus Section Tripped	11 kV Feeder Protection Operated
0 ms	23.7 ms	93.6 ms	+1000 ms (*outside of Disturbance Recording window*)

Table 5-2: Disturbance Recorder Currents

	Pre-AP Operation Current	AP Fault Current		Post-AP Operation Current	Post-Fault Current
Red	621.5 A	6418.0 A	6681.3 A	4573.7A	Not recorded
Yellow	618.4 A	5200.7 A	6072.9 A	4516.2 A	Not recorded
Blue	637.1 A	848.0 A	6727.8 A	4540.6 A	Not recorded
Residual	32.05 A	770.1 A	108.2 A	30.42 A	Not recorded

6 CONCLUSIONS

The fault as recorded on the disturbance recorder integral to the Adaptive Protection relay confirms the events observed from the CRMS up to the opening of the bus section circuit breaker. The initial operation of the Earth Fault and Neutral Current alarms correspond to the earth fault current seen in the disturbance records prior to the Adaptive Protection operation. The resetting of these alarms reflects the reduction of the residual current as the fault develops from a two phase to earth fault to three phase to earth fault

The reduction in the three-phase fault current due to the opening of the 11 kV bus section circuit breaker from 6681 A to 4573 A corresponds to system impedances of 0.786 pu and 1.148 pu on 100 MVA respectively. The change in impedance of 0.362 pu, corresponding to the reduction in fault current, compares well to the change in impedance expected by switching the bus section. Reverting to a single transformer from parallel transformers each of 0.80 pu on 100 MVA (see Fig 6-1) corresponds to a change of 0.4 pu on 100 MVA. Thus the observed fault current confirms the expected reduction in fault current.

The phase to phase to earth fault was present for 23.7 ms before the Adaptive Protection was triggered. In this case the fault current was only a multiple of 1.42 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.

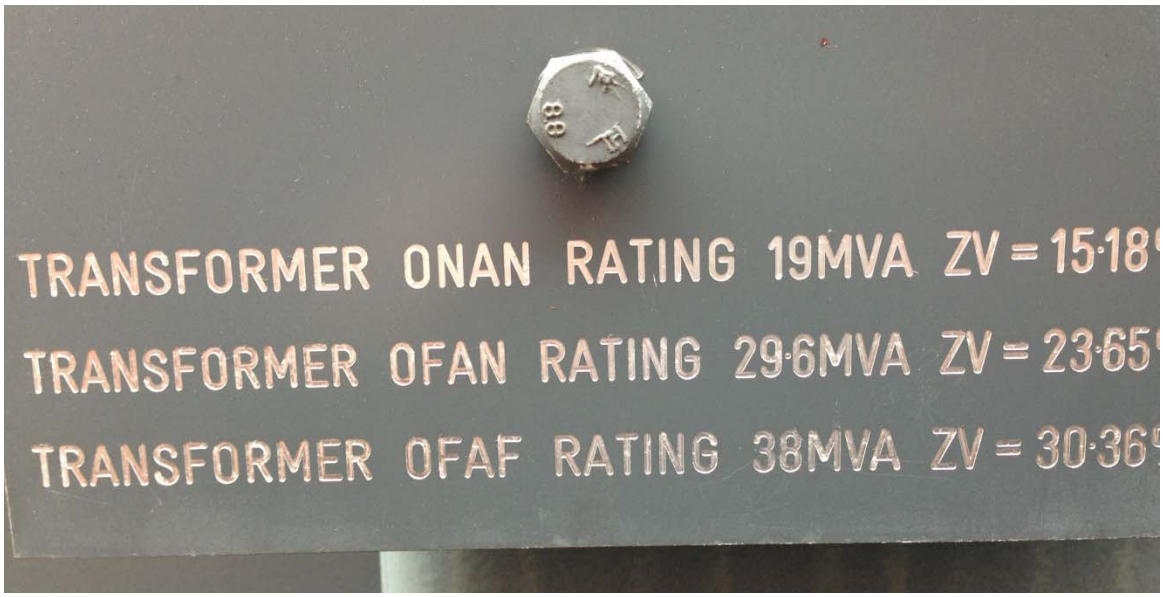

Figure 6-1: Atherton Town Centre transformer nameplate (Zpu = 0.80 pu = 15.18 x 100 / 19)