REPORT N^{O} 62104988

RESPOND POST FAULT ANALYSIS METHODOLOGY

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27TH MAY 2016

WSP | PARSONS BRINCKERHOFF

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Electricity North West Ltd

Confidential

Project no: 62104988
Date: 27th May 2016

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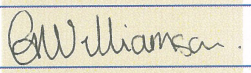
ISSUE/REVISION	FIRST ISSUE	REVISION 1	REVISION 2	REVISION 3
Remarks	Draft	Including client comments		
Date	May 2016	May 2016		
Prepared by	G Williamson	G Williamson		
Signature				
Checked by	P Watson	P Watson		
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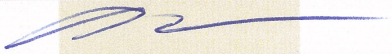
Authorised by	K Jackson	P Watson		
Signature				
Project number	62104988	62104988		
Report number	62104988-01	62104988-01		
File reference				

TABLE OF CONTENTS

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 to be trialled as part of the Respond project. Performance of these techniques will be assessed by examining the systems' behaviour in response to a fault. The methodology for undertaking this post-fault analysis is described in this report which is associated with the delivery of Successful Delivery Review Criteria, SDRC 9.3.1, as shown below.

CRITERIA	EVIDENCE
1.Design monitoring and analysis procedures for Trial regime;	1.Publish monitoring and analysis procedures for Trials on FLARE website

2 BACKGROUND

Distribution system fault levels are increasing as more Low Carbon Technologies are connected. Respond is seeking to trial alternatives to the traditional expensive and disruptive reinforcement approach necessary when fault levels exceed the capacity of network equipment.

Respond will deliver a Fault Level Assessment Tool (FLAT) which calculates potential fault current in near real time and then utilises one of three innovative techniques, two technical and one commercial, designed to manage fault current safely. The three Respond techniques are:-

Adaptive Protection

- The Adaptive Protection fault mitigation technique involves changing the sequence of operation of protection and circuit breaker switching such that the potential fault current is managed

Is-limiter

- Not presently employed in GB DNOs, Is-limiters are an existing technology which switches very quickly to limit the flow of fault current

Fault Current Limiting Service

- Fault Current Mitigation Service is a new commercial solution to be provided by customers switching generators or motors for the management of fault levels

Respond fault mitigation techniques will reduce the symmetrical RMS fault current flowing at the time that a circuit breaker opens to break a fault. It should be noted that protection associated with all fault mitigation techniques will only operate for three phase and phase-to-phase faults.

The three fault level mitigation technical solutions will be trialled at a total of 14 sites plus those yet to be identified associated with a new commercial approach, namely:

- Adaptive Protection: five installations on 11kV and 6.6kV High Voltage (HV) substations and two installations on 33kV Extra High Voltage (EHV) substations,
- Is-limiters at two HV substations,
- Is-limiter sensing units at three HV substations and two EHV substations, and
- Fault Current Mitigation Service, trial sites yet to be selected.

3 POST FAULT ANALYSIS REQUIREMENTS

3.1 POST FAULT ANALYSIS OBJECTIVE

The overall objective of the post fault analysis is to establish the satisfactory action of the fault mitigation techniques. This requires examination of information regards where the fault occurred, what happened as a consequence, when they happened and what the conditions were when the events occurred.

In particular the post fault analysis is required to:

- Establish the sequence and timing of events
- Check if the actions were as planned and expected for the particular fault level mitigation technique
- Quantify current flows throughout the event
- Establish that the correct actions were taken as a consequence of the flow of fault currents, including FLAT decisions and the enabling of the fault mitigation techniques before the fault

Interpretation of fault data is required to give an insight into the system conditions to establish if the correct action was taken. Understanding of the sequence of events is critical in discovering if there are any problems with the protection performance.

3.2 POST FAULT ANALYSIS INPUTS

The post fault analysis process is partly affected by the available information which depends upon existing data systems and equipment installed at the trial site. The following information sources are available:

Relating to all sites:

- **FLAT**, providing the following information:
    - If fault level mitigation technique was enabled at time of fault
    - When enabling was actioned (which may be a considerable time before the fault)

- **Control Room Management System (CRMS) system**, providing the following information:
    - Circuit Breaker status and status change - time stamped
    - High amps, but insufficient granularity to examine fault flows
    - Indication of protection operation (phases/earth fault flags)

Trial site dependent:

- **Numerical protection relays**, providing the following information:
    - Current waveforms / magnitude and duration
    - Operating time ('CB op time' in most numeric relays), although the clock may not be synchronised
    - Event capture
- **Electromechanical/Static protection relays**, providing:
    - no information beside indication that the protection has operated, except for phases/earth fault flags which indicate the nature of the fault
- **Additional Monitoring at the Is-Limiter locations *(yet to be decided)***
    - Power quality monitoring

The types of relay at each of the trial sites are listed in Table 3.1.

Table 3-1: Trial Site relay types

Technology to be Deployed		Substation	Voltage at Site	Protection at Site
Is-Limiter	HV Is-Limiter bus-section	BAMBER BRIDGE	11kV	Numerical/Microprocessor
	HV Is-Limiter - Incomer	BROADHEATH	11kV	Electromechanical
	EHV Is-Limiter sensing equipment	ATHLETIC ST	6.6kV, 33kV	6.6kV - Electromechanical 33kV - Electromechanical
		Wigan BSP (Gidlow CCT No 1)	6.6kV, 33kV	6.6kV - Electromechanical 33kV - Electromechanical
	HV Is-Limiter sensing equipment	LONGRIDGE	6.6kV	Mixture
		HAREHOLME	6.6kV	Static Electronic
		NELSON	6.6kV	Electromechanical
Adaptive Protection	EHV Adaptive Protection	MOUNT ST	6.6kV, 33kV	6.6kV - Electromechanical 33kV - Electromechanical
		OFFERTON	6.6kV, 33kV	6.6kV - Electromechanical 33kV - Electromechanical
	HV Adaptive Protection *(additional numerical relay to be installed)*	ATHERTON TC	11kV	Static Electronic
		DENTON WEST	33kV, 6.6kV	Electromechanical
		BLACKBULL	6.6kV	Numerical/Microprocessor
		IRLAM	6.6kV	Static Electronic
		LITTLEBOROUGH	6.6kV	Electromechanical

4 POST FAULT ANALYSIS METHODOLOGIES

4.1 IS LIMITER POST FAULT ANALYSIS METHODOLOGY

For the Is-Limiter fault mitigation technique, the post fault analysis is required to check that the correct sequence of events occurred, ie the mitigation technique was enabled correctly and the Is-Limiter operated before the protection.

Operation of the Is-Limiter automatically causes the opening of an isolation circuit breaker and the timing of this opening action will be available from the Control Room Monitoring System (CRMS)

When the fault current is available from a digital relay, it will be possible to establish whether the fault current at the time of fault clearance is attributable to a network configuration with one or two transformers by analysing the fault current magnitude. If it is observed that the fault current is consistent with one transformer only, it can then be deduced that the Is-Limiter operated to split the busbar or switch one of the parallel transformers out in advance of the operation of the protection.

4.2 PROTECTION ADAPTIVE PROTECTION POST FAULT ANALYSIS

For the Adaptive Protection fault mitigation technique, the post fault analysis is required to check that the correct protection was enabled by the FLAT and that the correct sequence of protection actions were taken at the appropriate levels of fault current. In particular, the response of Adaptive Protection to a fault should result in tripping of a bus-section or incomer primary transformer circuit breaker in advance of the faulted feeder's circuit breaker. The purpose of tripping a (bus-section or incoming primary transformer) circuit breaker in advance of the circuit breaker on the faulted feeder is to reduce the fault current flowing through the feeder circuit breaker before it clears the fault.

Although no relays will be replaced as part of the application of Adaptive Protection, an additional numerical relay will be installed at trial sites and so event recording including current waveforms will be available at all Adaptive Protection trial sites.

4.3 FAULT CURRENT LIMITING SERVICE METHODOLOGY

For the Fault Current Limiting Service fault mitigation technique, the post fault analysis is required to check if the participant's protection was enabled correctly due to the correct FLAT decisions and that the correct protection operated in the correct sequence. In particular, the response of the Fault Current Limiting Service to a fault should result in tripping of the participants' motor or generator in advance of the faulted feeder's circuit breaker.

Operation of the circuit breakers will be evident from the CRMS. It is assumed that a numerical relay will be available at all Fault Current Limiting participants' sites due to the need for it to be enabled and disabled remotely. A consequence is that it can be assumed that time tagged current measurements will be available for all such installations. Understanding of the event timing could be inferred from the magnitude of the recorded currents when the relay is not time synchronised with the CRMS.

4.4 ANALOGUE RELAY METHODOLOGY

Where analogue relays are used and current measurements are not available, an alternative approach is required in the absence of supplementary monitoring. Under these circumstances, the fault current will be calculated based on the system model and the fault location. Calculated fault

currents will be used to establish expected protection operating times and assess if they match with the observed post fault behaviour. It should be acknowledged that the post fault analysis accuracy will depend upon the protection and circuit breaker status time as recorded by the CRMS.

5 POST FAULT ANALYSIS PROCESS

Successful Delivery Review Criteria, SDRC 9.3.3, as detailed below, requires monitoring and post fault analysis to be evidenced by publishing a summary of each event on the project website. The process to achieve this is shown in **Error! Reference source not found.**.

CRITERIA	EVIDENCE
3. Implement monitoring and post fault analysis procedures in Trial period	3. Publish on FLARE 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;

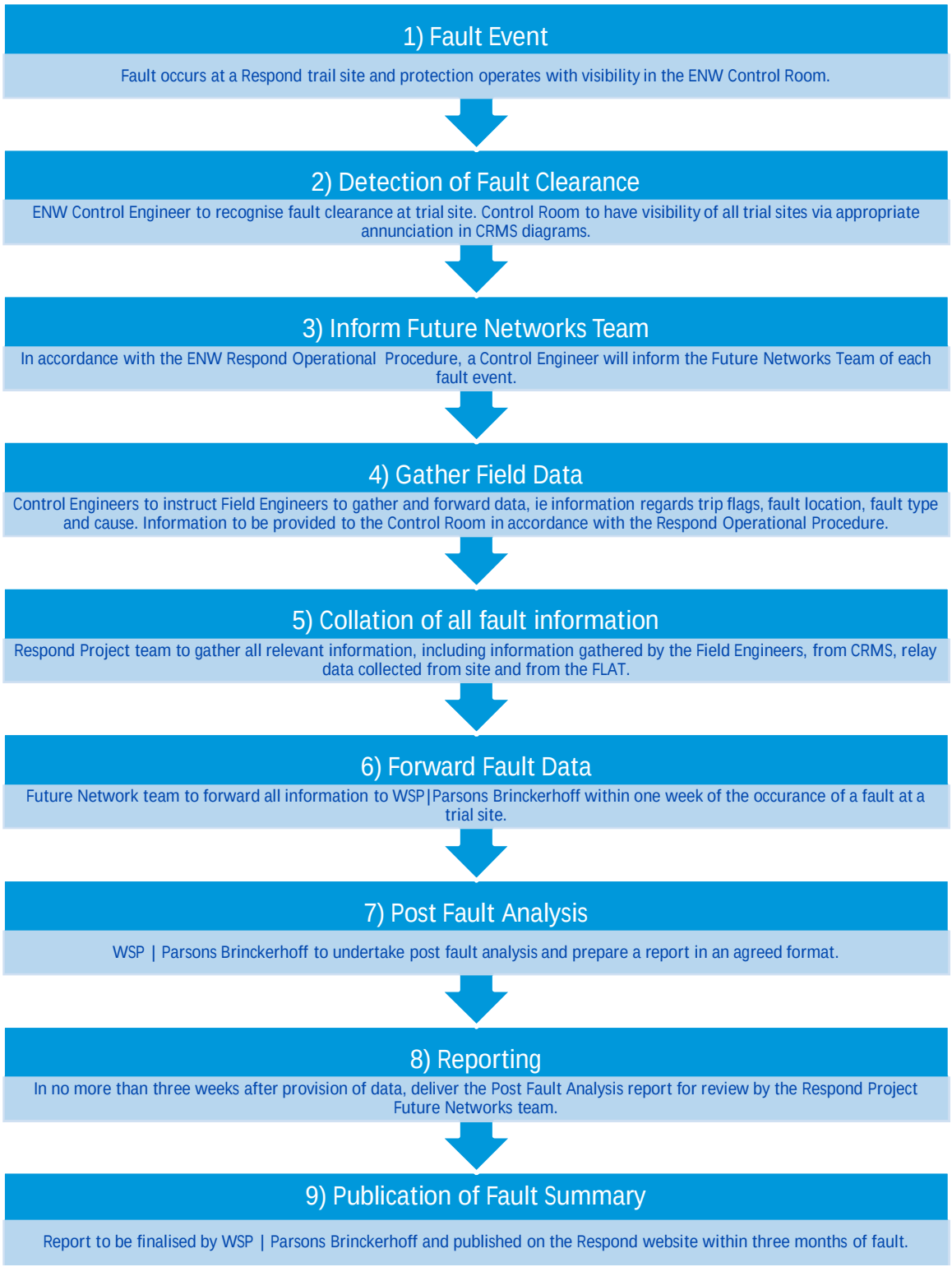


Figure 0-1: Post Fault Analysis Process

6 FAULT EVENT DATA REQUIREMENTS

The following data requirements are expected to be required for the post fault analysis:

- **Fault Event Information**
  - Date and time
  - Faulted circuit and location
  - CRMS records for circuit breaker operation (times and currents)
- **Network Data**
  - Pre-fault network configuration
  - Pre-fault voltages and network power flows
  - Post-fault network configuration
  - Network model for fault level calculation (when required)
- **Protection Data**
  - Protection settings
  - Event information depending upon relay type, ie phases/earth fault flags for electromechanical/static protection relays
  - Disturbance records including current magnitudes where available
  - Operation indications
- **Fault current Mitigation Technique Parameters**
  - Adaptive Protection Relay information including protection settings, disturbance records, current magnitudes and operation indications
  - Fault Current Limiting Service Relay information including protection settings, disturbance records, current magnitudes and operation indications
- **FLAT**
  - Status (enable/not enabled) of fault level mitigation techniques
  - Times associated with change in status

It is recommended that the numerical relay's pre-fault record and post-fault record length settings are checked at the start of the trial to ensure that satisfactory information is available for the post fault analysis. On the basis that the ultimate fault clearance may be slightly delayed by the application of the fault mitigation technique (in particular adaptive protection) and that the storage of a relay is typically 3s for a single record, we suggest 1s pre-fault and 2s post-fault. Triggering thresholds to initiate fault recording should also be checked to be appropriate.

7 FAULT EVENT ANALYSIS REPORTING

It is anticipated that the post fault analysis reporting will include the following as a minimum:

1) **Event Details**; identifier
2) **Fault Mitigation Details**; location, settings, etc.
3) **Fault Details**; date, time, location, type
4) **List of Data Sources**; protection, CRMS
5) **Event Time Line;** including FLAT actions, levels of current at each stage, protection operation and circuit breaker operation
6) **Event Analysis**; comparison of actual versus expected operation of the fault mitigation operation
7) **Conclusions**; judgement if the fault mitigation operated successfully and any recommendations, such as changes to settings