

Fault Restoration Performance on HV rings as part of the Capacity to Customers Project

Abstract

This paper describes the position to date of the restoration performance following five faults that have occurred on designated Capacity to Customers (C₂C) HV Trial rings. The closed ring operating configuration is being trialled as part of the project and it is important to evaluate for existing customers that their supply performance is not adversely affected using the closed ring network configuration. This paper details the post fault restoration sequences for the closed ring networks and compares this against a baseline of the respective radial network. The difference in performance is calculated based on Ofgem's Quality of Service metrics. In addition it explains any lessons learnt and improvements that have been made to the automation hardware or the control software following a fault operation.

All five fault occurrences demonstrate that when the network is configured as a closed ring customer interruptions (CI) and customer minutes lost (CML) are improved compared to the radial equivalent however short duration interruptions (SDI) are increased.

1. Introduction

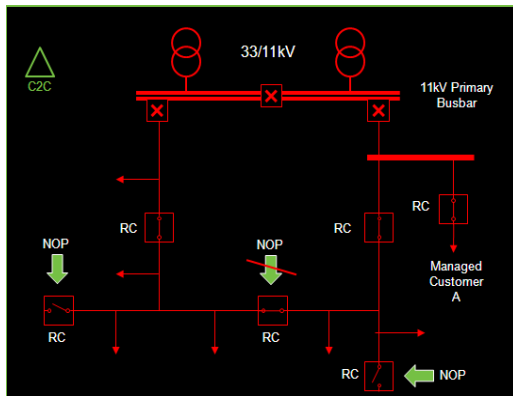
The aim of the C₂C Project is to test new technology, a number of network operational practices and new commercial demand response contracts that will allow Electricity North West to increase the loadings on a selection of Trial circuits representing approximately 10% of the HV network without resorting to conventional network reinforcement. Current EHV and HV network design philosophy promotes redundancy to achieve continuity of supply standards. The C₂C design philosophy however will use this inherent 'spare' capacity during normal network operation to accommodate demand increases but following a fault the use of automated switching will provide post fault demand response to manage power flows when operating with abnormal network configurations.

On the Trial circuits the existing network has been enhanced to provide the active management functionality required to operate the system within the new proposed commercial and technical arrangements. Proven low cost remote control has been installed at the Normal Open Point (NOP) between two adjacent radial circuits which can be closed to form a closed ring. At strategic intermediate points on circuits additional remote control has been installed to enable flexible rapid re-supply of customers following a fault. This is intended to decrease the amount of time that non-managed customers¹ are off supply due to a fault and minimise the need to utilise the demand management permitted by the new C₂C commercial demand response contracts.

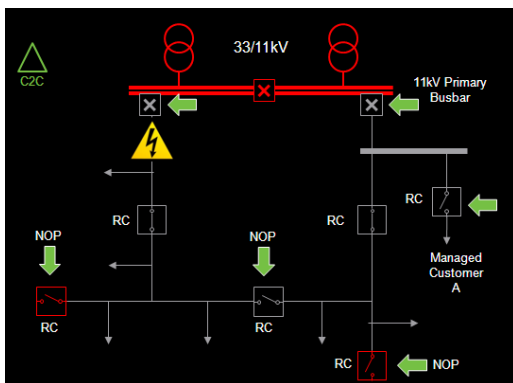
¹ A managed customer is an active Trial participant. Their supply is managed and controlled by Electricity North West without notice for the purpose of its demand response activities. The managed customer will receive regular payments or a discount on the cost of connecting to the network in exchange for having their supply managed.

Many of Electricity North West's 3,600 HV circuits typically suffer a fault no more than once every five years and consequently during the Trial 306 radial circuits have been meshed to create 153 closed ring networks. This is one type of operating configuration that will be tested during the Trial and aims to release additional latent capacity and initially reduce network losses by improving HV power flows. This paper details the restoration of managed and any non-managed customers¹ following five faults on closed ring C₂C Trial area networks. It also evaluates any degradation in post fault supply performance when the closed ring network configuration is implemented.

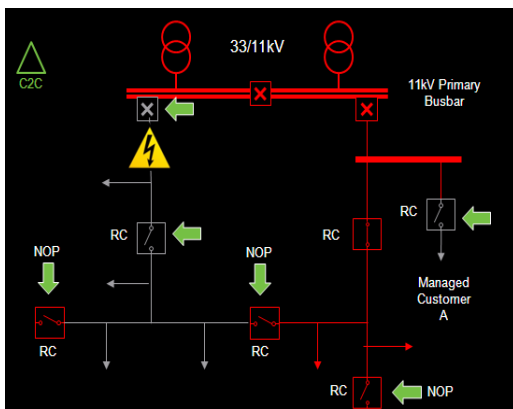
2. Example restoration sequence on a typical C₂C closed ring network



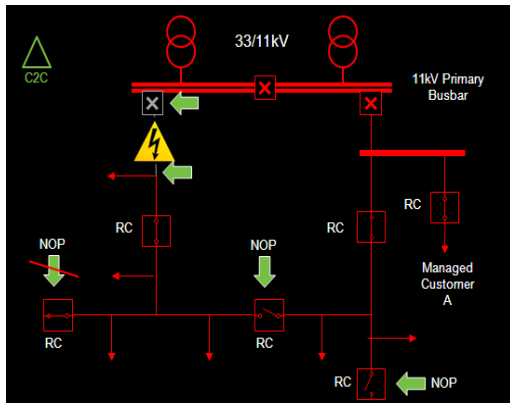
During normal running on a C₂C closed ring network the automated NOP connecting the two adjacent circuits will be closed. Also remote control will be installed at intermediate points on the network. In this example a C₂C managed customer is connected to the example network.



Following a fault on radial 1 the protection devices on both primary circuit breakers (CBs) will operate and both sides of the ring will suffer loss of supply. The Automatic Restoration Sequence (ARS) software will initiate the opening at the midpoint NOP and the switch controlling the managed customer.



The ARS software will then proceed to restore customers by trying to close one of the primary CBs. In this example radial 2 is closed and remains energised so all the non-managed customers on this radial will be restored. Knowing the fault is located on radial 1; ARS will instigate the opening of the intermediate point switch on radial 1 and close the primary CB. The failure of this enables the fault to be banded between the primary CB and the midpoint on radial 1.



The NOP between the two adjacent radials is then closed restoring supplies to all customers between this point and the intermediate point switch on radial 1. All of this automated switching will be completed within 3 minutes. Manual switching will then commence to move the NOP from this intermediate point switch to a substation closest to the fault and supplies to all non-managed customers excluding those on the faulty sections are typically restored within 1 hour. The ANM software then looks at optimising the available capacity of interconnected circuits to enable the managed customer to be restored.

3. Appraising the performance of closed ring networks

The closed ring network configuration being trialled as part of the project has the ability to release network capacity and initially reduce network losses. However it is important to ensure that for existing customers connected to these networks that the restoration of their supply following a fault is not adversely impacted.

As a means of comparing the performance of a closed ring the metrics used in Ofgem’s Quality of Service Incentive will be calculated and compared to the respective radial network that the fault has occurred on. The measures for comparison are: short duration interruptions², and number of customers interrupted per 100 customers (CI) and the number of customer minutes lost (CML).

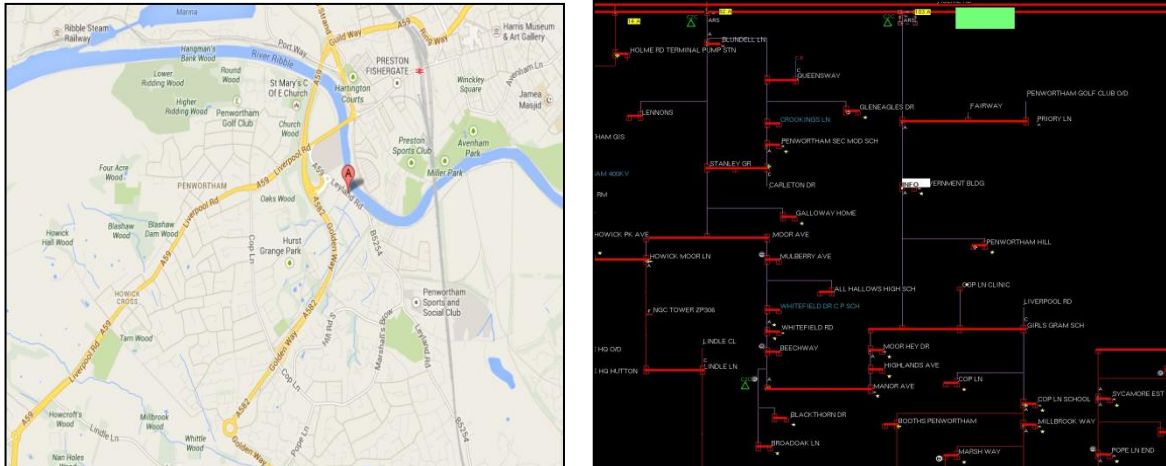
For each of the five faults that have occurred during the Trial period, the actual fault restoration sequence is detailed giving times and number of customers restored at each operation as well as an overview of the additional remote control (RC) that was installed a part of the project.

The theoretical restoration of the radial network follows the normal policy of splitting the network at the midpoint and following with a reclose at the primary to gain sectionalised location of the fault. For the purposes of evaluating the customer restoration times on the radial network it has been assumed that the remote control devices installed as part of the Trial would not be available and manual switching would commence at the same time as the first manual intervention as part of the closed ring restoration.

² Customers interrupted for less than three minutes. Currently under Ofgem’s Interruption Incentive Scheme these interruptions are not incentivised.

4. Trial period fault performance

I. Holme Road Primary – Priory Ln/ Blundell Ln (Ring No: 101)



Holme Road primary is south west of Preston town centre; it supplies approximately 13,000 mainly domestic and commercial customers. A fault occurred on the closed ring network 'Priory Ln/Blundell Ln' on the 11th July 2013. This network has no C₂C managed customers connected.

As part of the C₂C Trial, three additional RC devices were installed on the network; two further devices have since been installed due to network improvements.

Time	Closed ring restoration sequence - operation details
23:12	Both circuit breakers feeding ring trip. 4219 customers off supply
23:12	NOP at Whitefield Rd opens.
23:12	Primary reclose of Blundell Ln side of ring. 1665 customers restored.
23:14	Fault sectioned between RC devices on Priory Ln side of ring.
23:15	Primary reclose restores 467 customers up to Priory Ln substation.
23:16	RC device on Whitefield Rd substation closed to restore 661 customers up to Manor Avenue substation. ARS attempts to close RC device at Manor Avenue towards Moor Hey Drive. RC device at Manor Avenue status unknown.
23:18	Due to unknown status at Manor Ave, ARS opens the RC device at Whitefield Road. 661 customers off supply.
23:34	661 restored via control room initiated switching after confirmation of status of RC device at Manor Avenue.
23:51	390 customers restored between Manor Ave and Highlands Avenue via control room initiated RC switching.
00:16	243 customers restored at Moor Hey drive via control room initiated RC switching.
00:26	202 customers restored at Cop Lane School via control room initiated RD switching.
00:41	68 customers restored at Government Road via manual switching.
01:19	483 customers restored between Cop Lane and Liverpool Road via manual switching.
03:59	Generator dispatched for 41 customers on faulty section.

Fault time	Number of customers off supply			
	Radial Network		C ₂ C closed ring	
0	2554		4219	
3 minutes	2554		2087	
30 minutes	2554		1426	
1 hour	1244		1036	
1 hour 30 minutes	583		524	
2 hours	41		41	
Quality of Service Evaluation				
Short Duration Interruption	2554	£0	4219	£0
Customer Interruption	2554	£14,481 ²	2087	£11,833 ³
Customer Minutes Lost	155797	£44,973 ³	138090	£39,861 ⁴

The unknown status of the RC device and subsequent removal of supplies is a feature of ARS and in this instance resulted in further interruptions and delayed restoration of 661 customers.

II. Levenshulme – Barlow Rd/Cliftonia Works (Ring No: 114)



Levenshulme primary is in inner city Manchester; it supplies approximately 15,000 mainly domestic customers. A fault occurred on the closed ring network 'Barlow Rd / Cliftonia Works' on the 9th October 2013. This network has no C₂C managed customers connected.

No additional RC could be installed on the Barlow Rd feeder due to practical restrictions on the distribution switchgear and limited LV supplies. Therefore there

³ Based on 2013/14 Interruption Incentive Scheme value of £5.67 for each individual customer interrupted due to faults

⁴ Based on 2013/14 Interruption Incentive Scheme value of £17.32 for each customer hour lost due to faults

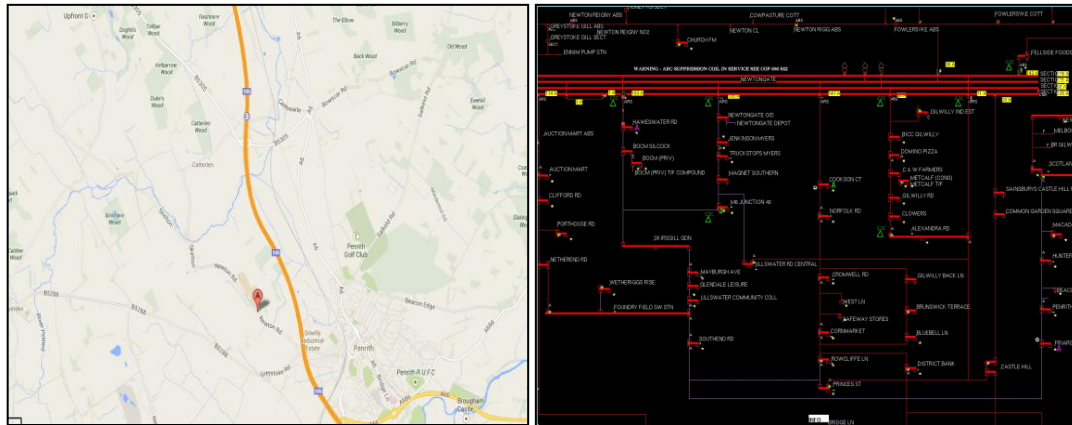
was no RC on the Barlow Rd feeder with the exception of the NOP at Sivori Ltd. substation.

Time	Closed ring restoration sequence - operation details
09:20	Both circuit breakers feeding ring trip. 2497 customers off supply
09:20	NOP at Sivori Ltd. substation opened
09:21	Primary reclose of Cliftonia Works side of ring, CB trips – no customers restored.
09:21	Open at Baslow Ave via RC
09:21	Primary reclose of Cliftonia works circuit. 1425 customers restored. Fault is bound between Baslow Ave and Sivori Ltd.
09:25	Primary reclose on Barlow Rd via control room initiated switching. 961 customers restored.
10:14	111 customers restored via manual switching of Baslow Ave to Tootals substation.

Fault time	Number of customers off supply			
	Radial Network		C ₂ C closed ring	
0	1536		2497	
3 minutes	1536		1071	
30 minutes	1536		111	
1 hour	111		0	
1 hour 30 minutes	29		0	
2 hours	0		0	
Quality of Service Evaluation				
Short Duration Interruption	1536	£0	2497	£0
Customer Interruption	1536	£8,709	1071	£6,073
Customer Minutes Lost	87810	£25,348	10799	£3,117

During this fault restoration unexpectedly the ARS software did not carry out a primary reclose on the Barlow Rd feeder when the fault was proved to be on the alternative feeder as there were no RC devices on this feeder. This resulted in the need for control directed switching and the 961 customers on this feeder being restored within five minutes. A software alteration has been made to resolve this issue.

III. Newtongate Primary – Haweswater Rd/ Newtongate O/D (Ring No: 136)

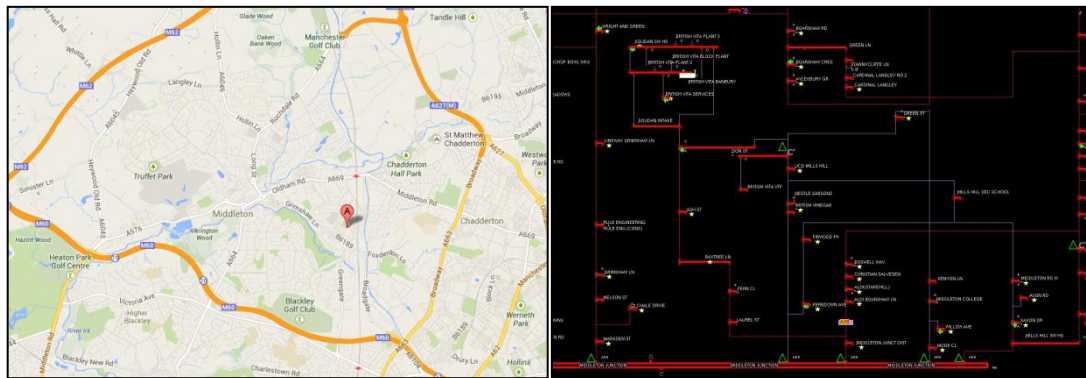


Newtongate primary supplies 10,000 customers in Penrith and the surrounding area. A fault occurred on the 'Haweswater Rd/ Newtongate O/D' closed ring network on the 18th November 2013. This network has no managed C₂C managed customers connected.

Time	Closed ring restoration sequence - operation details
06:18	Both circuit breakers feeding ring trip. 1268 customers off supply
06:19	NOP at M6 Junction 40 substation opened
06:19	Primary reclose of Haweswater Rd side of ring. 1132 customers restored.
06:20	Open at Truckstops Myer substation.
06:21	Reclose primary up to Jenkinson Myers, 64 customer restored. Fault is bound between Truckstops Myer and Magnet southern.
06:59	40 customers restored at Ullswater Road Central by manual switching
07:18	16 customers restored at M6 Junction 40 substation by manual switching
07:38	16 customers restored at Truckstop Myers substations by manual switching.

Fault time	Number of customers off supply			
	Radial Network	C ₂ C closed ring		
0	136	1268		
3 minutes	136	72		
30 minutes	136	72		
1 hour	57	16		
1 hour 30 minutes	0	0		
2 hours	0	0		
Quality of Service Evaluation				
Short Duration Interruption	136	£0	1268	£0
Customer Interruption	136	£771	72	£408
Customer Minutes Lost	9870	£2,849	4040	£1,166

IV. Middleton Junction Primary – British Vinegar/Ferndown Ave // Moor CI (Ring No: 121)

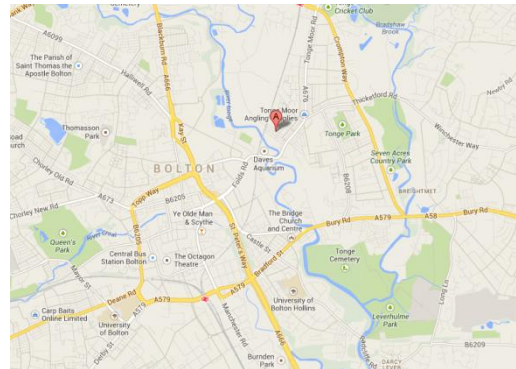
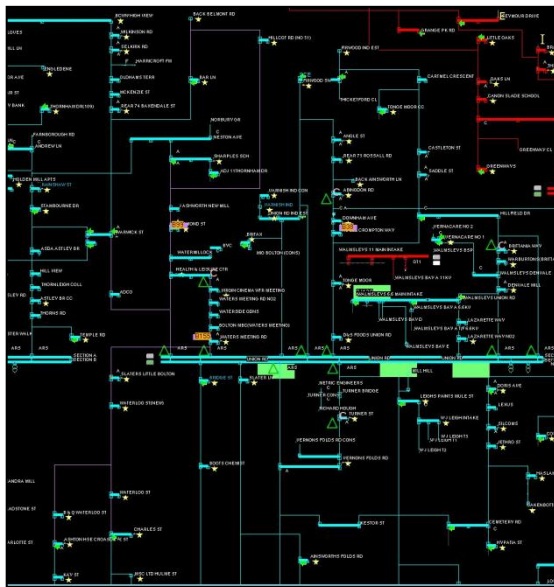


Middleton primary supplies 8,000 predominantly domestic and commercial customers in north Manchester. A fault occurred on the 'British Vinegar/Ferndown Ave // Moor CI' closed ring network on the 24th November 2013. This network has no managed C₂C managed customers connected.

Time	Closed ring restoration sequence - operation details
10:05	Both circuit breakers feeding ring trip. 2916 customers off supply
10:06	NOP at Don St opened
10:06	Primary reclose of British Vinegar/Ferndown Avenue side of ring. 1650 customers restored.
10:06	Open at Green St substation and Middleton College via RC
10:07	Primary reclose to Middleton College, CB trips. Fault bound between these two points.
10:08	166 customers restored at Don St via RC switching.
10:09	349 customers restored at Green St via RC switching.
10:35	572 customers restored at Moor Close via manual switching.
11:08	179 customers restored at Willow Avenue via manual switching on the LV network.

Fault time	Number of customers off supply			
	Radial Network		C ₂ C closed ring	
0	1266	£0	2916	£0
3 minutes	1266		1100	
30 minutes	1101		179	
1 hour	529		179	
1 hour 30 minutes	179		0	
2 hours	0		0	
Quality of Service Evaluation				
Short Duration Interruption	1266	£0	2916	£0
Customer Interruption	1266	£7,178	1100	£6,237
Customer Minutes Lost	61362	£17,713	29833	£8,612

V. Union Road – Slater Little Bolton/Health and Leisure Centre (Ring No: 169)



Union Road primary supplies 10,000 predominantly domestic and commercial customers in Bolton. A fault occurred on the 'Slater Little Bolton / Health & Leisure Centre' closed ring network on the 2nd November 2013. This network has no managed C₂C managed customers connected.

Time	Closed ring restoration sequence - operation details
14:32	Both circuit breakers feeding ring trip. 2040 customers off supply
14:32	NOP at Health & Leisure Centre substation opened
14:34	Primary reclose of Slater Little Bolton side of ring, CB trips.
14:34	Primary reclose on Health & Leisure Centre circuit, 1684 customers restored.
14:34	Open via RC at Slaters Little Bolton substation towards Waterloo St(New).
15:02	206 customers restored via manual switching by closing at Ashton Hse Croasdale St substation.
15:31	150 customers restored via manual switching by closing at Health & Leisure Centre substation towards Waters Meeting Rd.

Fault time	Number of customers off supply			
	Radial Network		C ₂ C closed ring	
0	356	£0	2040	£0
3 minutes	356		356	
30 minutes	356		150	
1 hour	150		0	
1 hour 30 minutes	0		0	
2 hours	0		0	
Quality of Service Evaluation				
Short Duration Interruption	356	£0	2040	£0
Customer Interruption	356	£2,018	356	£2,018
Customer Minutes Lost	25860	£7,465	15030	£4,339

5. Conclusion

All five fault occurrences demonstrate that when the network is configured as a closed ring, customer interruptions (CI) and customer minutes lost (CML) are improved compared to the radial equivalent however the initial short duration interruptions (SDI) are increased.

During the Trial a series of customer surveys has been conducted to monitor the effects of the Trial on customers. From the interviews conducted to date the findings suggest that for domestic customers the introduction of C₂C and the closed ring network configuration has improved the perception of the occurrence of faults. As the examples in this paper show that under C₂C closed ring conditions faults are generally shorter in duration than faults on typical radial circuits and as a result possibly harder to detect.

The software and hardware required to optimise the post fault restoration of closed rings has performed effectively in most instances and where limitations have been highlighted improvements have been developed.

Further work by our academic partners will evaluate the range benefits that can be realised from C₂C closed ring operation in conjunction with the required network investment.

The Trial is scheduled to continue until September 2014 at which time lessons learned and findings will be collated in more detail and communicated to all interest stakeholders via a range of knowledge dissemination routes including conferences, closedown reports and additional white papers. Further information on the Capacity to Customers Project can be found on our website at www.enwl.co.uk/c2c