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**Appointed examiner's audit of Exceptional Event Claim -  
Electricity Northwest Limited - Blackburn Group  
30 April 2013**



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## Authorisation

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## Glossary

Abbreviation	Meaning
AE	Appointed Examiner
CB	Circuit-breaker
CEGB	Central Electricity Generating Board
CI	Customer Interruptions per 100 connected customers
CML	Customer Minutes Lost per connected customer
DNO	Distribution Network Operator
EHV	Extra High Voltage – all voltages above 20kV up to but excluding 132kV
ENWL	Electricity Northwest Limited
ep	energypeople
HV	High Voltage – all voltages above 1kV up to and including 20kV
QoS	Quality of Service
RIGs	Regulatory Instructions & Guidance
SCADA	Supervisory Control and Data Acquisition
SLD	Single Line Diagram
SoF	Statement of Facts
ToR	Terms of Reference

### Notes:

Within this document:

1. The term “higher voltage” is used to indicate all voltages greater than 1kV.
2. The calculations of CI and CML within this document are adapted from the annual calculations contained in the RIGs to reflect the CI and CML generated by the actual incidents being audited.

They are as follows:

CI: the number of interruptions to supply – the number of customers interrupted per 100 connected customers generated by the incidents being audited.

It is calculated as:

$$CI = \frac{\text{the sum of the number of customers interrupted for incidents being audited} * 100}{\text{the total number of connected customers}}$$

CML: the duration of interruptions to supply – the number of customers interrupted per connected customer generated by the incidents being audited.

It is calculated as:

$$CML = \frac{\text{the sum of the customer minutes lost for all restoration stages for incidents being audited}}{\text{the total number of connected customers}}$$

In both the formulae above, the total number of connected customers is as declared as at 30 September during the relevant reporting year. Any claims that occur and are audited prior to 30 September in the reporting year during which they occur will be audited using the total number of customers declared at 30 September in the previous reporting year.



## Summary

1. Ofgem has commissioned energypeople as its Appointed Examiner (AE) to audit the submission made by Electricity Northwest Limited (ENWL) under the "one off" exceptional event mechanism that, on Tuesday 30 April 2013, two inter-related incidents within the "Blackburn Group" of ENWL's 132/33kV distribution system adversely affected the reported performance for its licensed area for regulatory reporting year 2013/14.
2. One incident was the catastrophic failure of ENWL's 132/33kV number 1 Grid Transformer at its Blackburn Grid Substation and the inter-related incident was the failure of a joint on a 33kV fluid-filled underground cable during the ensuing load-balancing and optimisation of ENWL's system.
3. The AE has visited ENWL to audit the claim against part 1 of the "one-off" exceptional event process and finds that it passes the exceptionality threshold in terms of CI but not CML.
4. The AE concludes that the event falls within the category of an "other event" as defined in paragraph 8.57 of Special Licence Condition CRC 8, including meeting the exceptionality requirements set out in Appendix 3 thereof.
5. The AE therefore proceeded to part 2 of the "one-off" exceptional event process, assessing ENWL's performance in mitigating the impact of the event upon its customers.
6. The AE concludes that the internal failure of ENWL's number 1 132/33kV Grid Transformer at its Blackburn Grid Substation was due to an undetectable internal manufacturing defect and beyond ENWL's control.
7. The AE considers that the continuous monitoring of all its pressurised systems within ENWL's SCADA system is representative of international best practice and, with the lack of incidents on the fluid-assisted circuit that faulted; the AE concludes that ENWL could not have done more to ensure this 33kV circuit was free from latent defects.
8. The AE considers that ENWL's protection operated correctly to clear the incidents from its distribution system.
9. The AE commends ENWL for its learning point resulting from this incident whereby ENWL has already inspected its seventeen similar Grid Transformers and found them to be clear of the manufacturing defect that caused the failure of the number 1 Grid Transformer at Blackburn Grid Substation.
10. The AE also commends ENWL's control engineers for analysing the alarms generated by the incidents and for restoring all supplies as quickly as possible.
11. The AE concludes that ENWL had met the criteria of Appendix 4 to paragraph 8.58 of Special Licence Condition CRC 8 and that therefore the incident is deemed to be eligible for adjustment in the DNO's reported performance.
12. The AE therefore recommends that an adjustment to ENWL's 2013/14 reported distribution system performance is made, in line with the part 1 audited CI and CML figures as shown in the following table:

	Audited number	Number above the threshold	Recommended adjustment
CI	1.49	0.39	0.39
CML	0.41	0.00	0.00



## 1. Audit part 1

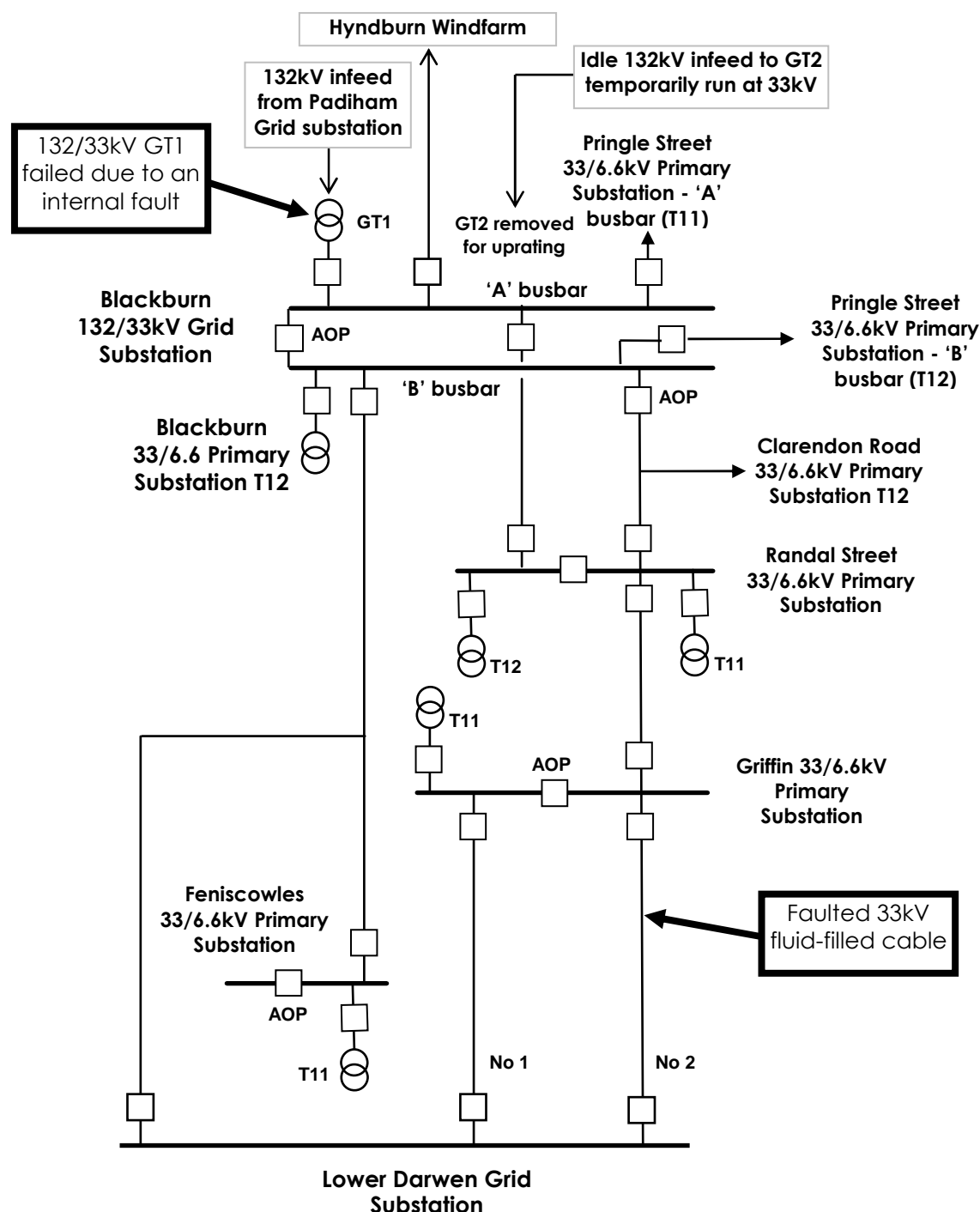
### 1.1 Summary of the main facts

13. The AE's headline information log for this event is set out in Table A-1 at Appendix A. In addition, the following paragraphs summarise the main facts of the event.
14. ENWL has provided evidence to support its claim that a latent manufacturing defect within the tap-changer of the number 1 132/33kV Grid Transformer at its Blackburn Grid Substation created a catastrophic failure that resulted in the loss of supply to all 33kV outfeeds from the site.
15. ENWL has also provided evidence to support its claim that the failure of a 33kV underground feeder that was being relied upon during the optimisation of the ensuing load-balancing on its distribution system resulted in further loss of supplies to its customers.
16. This 33kV underground cable failed due to a latent defect in a fluid-filled cable joint and reduced ENWL's EHV system to an "N-3" situation.
17. ENWL's distribution system was severely stretched. ENWL had to deploy mobile generation to both restore customers' supplies and to balance the loading on its distribution system. A 6% voltage reduction was also applied to reduce the loading on the affected parts of the network.
18. The 33kV infeeds to eight of ENWL's 33/6.6kV Primary Substations were lost during the course of the event, with a total of 35,928 customers' supplies being interrupted for three minutes or longer.
19. A further 46,688 of ENWL's customers suffered a short interruption during the course of the supply restoration activity. These customers' supplies were restored by a combination of ENWL's sophisticated automated restoration equipment and tele-controlled switching by ENWL's control engineer.
20. ENWL's protection operated correctly to clear the incidents from its distribution system.
21. ENWL's distribution system was running abnormally at the time of the incident due to the number 2 132kV infeed to its Blackburn Grid Substation being under an outage to replace the number 2 132/33kV Grid Transformer with a higher capacity unit.
22. It should be noted that ENWL's number 1 132/33kV Grid Transformer at its Blackburn Grid Substation had only recently been changed to a higher capacity unit which was energised on 09 November 2012.
23. Despite the deployment of mobile generation, the peak loading on ENWL's system would have been too high for ENWL's system to sustain with both the 132/33kV Grid Transformer and the underground 33kV circuit out of service and ENWL therefore drew-up contingency plans to rotate the available power to its customers.
24. However, in order to avoid further hardship to its customers with the possibility of periods without supply, ENWL elected to re-energise the faulted 33kV fluid-filled underground cable by continuously pumping the leaking hydraulic section so as to maintain pressure within the cable and to restore its electrical integrity.
25. By this means, ENWL avoided having to deliberately disconnect its customers.



26. Also, ENWL's engineering team made use of the then currently idle number 2 132kV infeed to its Blackburn Grid Substation by energising it at 33kV and thus provided an invaluable infeed into the severely depleted section ("Blackburn Group") of its distribution system.
27. As noted above, this 132kV infeed was currently idle due to the outage to replace the number 2 132/33kV Grid Transformer at Blackburn Grid Substation.
28. Once energised, this temporary arrangement enabled ENWL to de-energise the faulted 33kV underground cable, locate and repair the fluid leak and return the cable to service, thus maximising the security of supply to its customers in the Blackburn Group.
29. The faulted number 1 132/33kV Grid Transformer was removed from its plinth and taken to the manufacturer's premises in Germany for detailed investigation.
30. Meanwhile, ENWL's engineering team replaced the faulted unit with the unit intended to become the uprated number 2 Grid Transformer.
31. After extensive investigation by the manufacturers, the cause of the failure of the number 1 132/33kV Grid Transformer was found to be a "one-off" manufacturing defect within the tap-changer.
32. The cause of the failure of the 33kV fluid-filled underground cable joint was found to be the rupturing of the conical 'end-piece' of the metal sleeve surrounding the conductors of the joint itself.
33. Apart from the on-going outage to replace the number 2 132/33kV Grid Transformer at its Blackburn Grid Substation, ENWL's network was restored to normal running once the replacement for the faulted number 1 132/33kV Grid Transformer had been commissioned.
34. A simplified view of the sections of ENWL's 132/33/6.6kV networks affected by this event is shown in Figure 1.

Figure 1 – Simplified Network Diagram of ENWL's 132/33/6.6kV distribution networks affected by the incident



**Notes:**

1. Only the salient items of switchgear are shown.
2. At the time of the failure of GT1 ENWL's network was running abnormally - the number 2 132kV infeed to Blackburn Grid Substation was under an outage to replace GT2.
3. Following the failure of GT1 ENWL's 33kV and 6.6kV networks were configured as above - "AOP" in the above diagram indicates abnormal open points following the failure of GT1.
4. Only those 33/6.6kV transformers carrying load are shown – to balance the loading on the system Blackburn, Clarendon Road, Feniscowles and Griffin Primary Substations were all running on a single 33/6.6kV transformer.
5. Also, the 6.6kV busbar at Pringle Street Primary Substation was running with the bus-section circuit-breaker open.



## 2. Exceptionality requirements

### 2.1 Does the event qualify for exclusion

35. The AE considers that the event falls within the category of an "other event" as defined in paragraph 8.57 of Special Licence Condition CRC 8, and meets the exceptionality requirements set out in Appendix 3 thereof.
36. The AE therefore considers that, subject to satisfying the requirements of Appendix 4 to CRC 8, the event qualifies for possible exclusion under the "one-off" exceptional events process.

### 2.2 Exceptionality test results

37. The number of incidents attributed to the event is shown in Table 1.

**Table 1 – The number of incidents attributed to the event**

Number of incidents attributed to the event	Claimed number	Audited number
132kV	1	1
EHV	1	1
HV	0	0
LV	0	0
<b>Total</b>	<b>2</b>	<b>2</b>

38. The results calculated by the AE to test this claim against Ofgem's exceptionality criteria are shown in Appendix A. A summary of the results is shown in Table 2.

**Table 2 – Summary of exceptionality test results**

Test	Threshold	Claimed number	Audited number	Pass / Fail	Amount above threshold
<b>CI exceptionality</b>	1.10	1.49	1.49	Pass	0.39
<b>CML exceptionality</b>	0.80	0.41	0.41	Fail	0.00

**Notes:**

1. These figures are based on the customer numbers as at 30 September 2013.
2. Ofgem's CI and CML exceptionality criteria are set out in the AE's ToR<sup>1</sup>.
3. The audited CI and CML used in the exceptionality test have been determined from the number of incidents attributed to the event.
4. Where the event passes either or both the exceptionality thresholds, the amount(s) above the threshold(s) is/are carried forward into the Audit part 2 assessment of DNO performance.
5. In accordance with guidance from Ofgem, the AE's calculations use the threshold values contained in the current Distribution Price Control and the number of customers connected to the DNO's network relevant to the date on which the incident occurred.

<sup>1</sup> Audits of Electricity Distribution Network Operators' one-off Exceptional Events Claims for 2012/13 to 2014/15



### 3. ENWL's views of its performance

#### 3.1 Dealing with the event

39. ENWL's 132/33kV Blackburn Grid Substation is normally supplied via a dual circuit 132kV tower line from National Grid's Padiham Grid Supply Substation.
40. Work was on-going at Blackburn Grid Substation to uprate both 132/33kV Grid Transformers.
41. The number 1 Grid Transformer had been replaced and was on load; the number 2 Grid Transformer had been removed; and personnel were on site to install a new plinth and bunding prior to the uprated number 2 unit being installed.
42. Thus, at the time of the failure of the tap-changer within the number 1 Grid Transformer, Blackburn Grid Substation was on a single 132kV infeed.
43. ENWL's automated control system operated to restore 12,450 customers' supplies within three minutes.
44. The remaining 14,021 customers were restored in stages by ENWL's control engineer using tele-controlled switching.
45. In order to achieve this, ENWL had to operate its 33kV system in an abnormal configuration so as to optimise the load balance across the alternative sources.
46. As shown in Figure 1; at this stage the 33kV circuit from Lower Darwen Grid Substation to Blackburn Grid Substation feed Feniscowles Primary Substation was supplying the 'A' busbar at Blackburn Grid Substation; Feniscowles and Griffin Primary Substation loads were being supplied via the number 1 33kV circuit from Lower Darwen Grid Substation to Griffin 'A' busbar; and the number 2 33kV circuit from Lower Darwen Grid Substation to Griffin Grid Substation was supplying the 'B' busbar at Blackburn Grid Substation via Randal Street Primary Substation.
47. ENWL deployed mobile generators to try to maintain the system within balance and applied a 6% voltage reduction to reduce the overall demand within the Blackburn Group.
48. With the above abnormalities, it was necessary for ENWL's control engineers to continuously monitor the loading on the affected distribution system, and to use tele-controlled switching to adjust the balance on the 6.6kV system as the loads increased towards the evening peak.
49. At Blackburn Grid Substation, ENWL immediately initiated continuous working on the activities relating to the replacement of the number 2 Grid Transformer; contacted the manufacturers to advise of the catastrophic failure of the number 1 unit and began preparation for its removal from site.
50. At 17:33, as the tea-time peak approached, the number 2 33kV circuit from Lower Darwen Grid Substation to Griffin Primary Substation failed, resulting in the loss of the infeed to the 'A' busbar at Blackburn Grid Substation and loss of supplies to ENWL's customers being fed from Clarendon Road, the 'A' busbar at Pringle Street and Randal Street Primary Substations.
51. Further load could not be removed from the Blackburn Group and, in re-balancing the loading on the severely depleted system, the 33kV circuit from Lower Darwen Grid Substation to Blackburn Grid Substation feed Feniscowles Primary Substation tripped, resulting in the loss of supplies to ENWL's customers fed from Blackburn and the 'B' busbar at Pringle Street Primary Substations.



52. ENWL's control engineers used tele-controlled switching to restore as many customers as possible and called for more mobile generation to assist them to control the loading and hence the balance of the system.
53. Realising that the above measures would not necessarily avoid the need to deliberately disconnect its customers, ENWL took the decision to risk re-energising the failed fluid-filled 33kV circuit and to continuously pressure the hydraulic system using its own fleet of mobile pumping vehicles.
54. By this means ENWL avoided having to disconnect its customers, a fact of which it is proud.
55. ENWL advised the Environment Agency of the situation and began to consider alternative sources of 33kV infeeds to support its severely depleted Blackburn Group.
56. It was at this stage that ENWL's engineering team developed the idea to operate the then idle 132kV infeed into Blackburn Grid Substation at 33kV to give much needed relief to its distribution system and to allow the shutdown of the leaking fluid-filled cable to detect and mend the leak.
57. Thus work began at 'first light' to install a connection to the idle 132kV infeed from the 33kV system at Huncoat Grid Substation (the 'sending end') and to connect the 'receiving end' to the 33kV busbar at Blackburn Grid Substation.
58. ENWL is also proud of this initiative and of its people in having the work completed and this temporary infeed energised on 16 May 2013.
59. ENWL considers that its protection operated correctly to clear the incidents from the system.
60. ENWL considers that its automated switching equipment worked correctly in restoring as many customers as possible within three minutes.
61. ENWL also considers that its duty control engineer reacted well in assessing the alarms generated by the event and commencing tele-controlled switching of alternative supplies.
62. ENWL also considers that its engineering team did well in re-energising the failed 33kV fluid-filled cable so as to avoid the need for deliberate supply disconnections.

### **3.2 ENWL's answers to questions on its performance**

63. Within the last four years, the AE has reviewed ENWL's design standards, construction methods and maintenance procedures during previous visits to audit exceptional event claims and found them fit for purpose.
64. The AE confirms that ENWL's emergency procedures provide for the type of event being examined here.
65. To aid understanding of the background to ENWL's Statement of Facts (SoF), the AE prepared a list of initial questions regarding this incident. These questions were used as the basis for the examination of ENWL's claim.
66. The initial questions were discussed during the AE's visit to ENWL's Manchester Control Centre on 29 September 2014, when the records of ENWL's SCADA system, the incident reports and other information were made available.
67. ENWL has provided answers to the AE's initial list of questions. For ease of reference, the AE's questions are printed in bold font with ENWL's answers being printed in normal font.



**Q1. What, if any, changes has ENWL made to its emergency plans and procedures since the Appointed Examiner (AE) last visited to audit the exceptional event claim concerning the incident that occurred on 27 October 2010 which affected ENWL's customers supplied from its Wigan Grid Substation?**

- A1. Our code of practice 604 undergoes annual review following all major events and storms. Since 2010 we have improved clarity on customer communications, strengthened the role of the local incident centre and significantly improved our procedures for liaison with Local Resilience Forums, DECC and Ofgem during such events. We have also improved our social media engagement to ensure customers remain fully informed.

In our investment plans we have recognised the potential for such events to cause significant disruption to our customers' supplies and have reinvested over £4 million of efficiencies in improved 33kV and 11kV interconnection capacity. This move represents a major investment in network resilience and arose as a result of the Wigan incident. This investment was utilised most recently at Carr Street where a new interconnector enabled automated supply restoration following loss of a transformer co-incident with a transformer outage.

To ensure such transfer capacity is fully utilised in such events we have improved remote control of critical network open points and enhanced our automation software to exploit this capacity in less than three minutes. In total we have invested over £10m in additional network remote control to facilitate remote supply restoration during fault events.

This investment directly benefitted the customers affected by this event restoring some 12,720 customers within 3 minutes of the GT1 transformer. In our view no other DNO has invested in such automated restoration software capable of restoring large scale losses of supply.

**Q2. When did the outage to replace GT2 at Blackburn Grid Substation begin?**

- A2. Outage reference n° 00838N2013 on Blackburn GT2 commenced on 14<sup>th</sup> March 2103 at 09:30.

**Q3. Other than the post-fault contingency plans included in ENWL's SoF, what considerations were given to reduce the demand on the Blackburn Group during this outage?**

- A3. The anticipated maximum demand at Blackburn during this outage was 48.5MVA versus the 90MVA rating of the new GT1 transformer. As such the demand was well within the capability of GT1 and load transfers were not deemed necessary to allow the GT2 outage to proceed.

To implement demand transfer it would have been possible to transfer Randle Street onto Lower Darwen however this would have necessitated running all three primary substations at single 33kV circuit risk. This would have placed customers at greater risk than the selected configuration; as the probability of a 33kV circuit fault is several times higher than that of a 132kV line or GT fault.

Where equivalent security can be attained by demand transfer then it is our normal practice to secure demand utilising this method. Where such transfers would increase risk to customers it is not our policy to transfer demand.



**Q4. It is not clear from the SoF how ENWL's 33kV system was running following the restoration of supplies after the failure of GT1 and prior to the failure of the 33kV fluid-filled cable. Can ENWL please clarify this and explain the situation regarding any temporary supply arrangements following the failure of GT1?**

A4. We will demonstrate the 33kV system of ENWL's Blackburn Group after the restoration of supplies following the failure of GT1 to the AE during the audit visit. It will be shown that the system emanating from Lower Darwen Grid Substation is 'split' to balance the loadings and to keep the system stable. A 6% voltage reduction was applied and some temporary mobile generation was deployed at various Distribution Substations in an effort to keep the overall demand well within the emergency overload capacities of the system components with some 'headroom' for the evening peak load.

Please note that at this stage the system was operating in an abnormal and temporary running arrangement optimally configured to minimise loss of supplies in the event of a third fault. However the system was not normal, system switching was still underway to balance loadings and secure supplies across the load profile and customers were fed from temporary alternate supplies due to the GT1 fault.

Unfortunately, one of the 33kV backfeeds subsequently failed. This failure arose as a result of the reconfiguration triggered by the first fault and revealed a latent fault on the 33kV feeder.

These incidents are directly related and placed the system at N-3. N-3 events are highly abnormal and considerably beyond mandated design standards and hence by definition exceptional. The nature of the GT1 fault was not in our opinion reasonably foreseeable; as the new unit had been on load for some time prior to the fault and had operated normally. Nor was the latent feeder fault foreseeable as there had been no previous indication of this issue and the feeder was operated within its normal rating.

As noted below in A12 and A14 the cable had no recent history of leakage and was continuously monitored by SCADA for oil pressure issues – all of these showed the circuit to be in good condition. *[AE's note: ENWL's diagram provided a most useful aid in understanding the running arrangements of the 33kV system and shows how severely depleted it is when the n° 2 circuit 33kV between Lower Darwen and Griffin fails. The fact that mobile generation was also deployed following the failure of GT1 adds to the temporary arrangements that ENWL had to put in place. A simplified version of the running arrangement is shown in Figure 1 of this report].*

**Q5. What protection operated to clear the faulted GT1 at Blackburn Grid Substation?**

A5. GT1 Main Transformer Protection (Overall bias differential) and main tank Buchholz trip. The 132kV mesh corner auto isolated as normal and the Delayed Auto Reclose system installed did not reclose on GT1 exactly in accordance with the system design. All protection systems operated normally and correctly.

As a result of the fault the main transformer tank explosion vents also operated venting the extreme internal pressure caused by the internal arc. Oil was ejected from the main tank but retained within the bunding systems.

Staff working on site contacted the control centre to report the trip and the noise of the venting.





**Q6. In the last paragraph on page 2, the SoF states: “To restore the customers all the demand from Blackburn BSP was transferred through three 33kV circuits to Lower Darwen BSP. This is an adjacent BSP with capacity to support the group at this point on the load cycle”. What is meant by the expression ‘load cycle’ and, in this context, over what time period does it relate?**

A6. The statement relates to the planned outage period and indicates that with the three interconnectors available all of the demand could be restored for loss of GT1. This was true regardless of the status of the DG at this point in time in the annual load cycle. *[AE’s note: this was discussed during the audit visit – in particular, the reliability of the three 33kV circuits being used to backfeed Blackburn Grid Substation following the loss of GT1 plus the variability and hence lack of reliance that ENWL could place upon any infeed from the Hyndburn Wind Farm – the ‘DG’ referred to in A6 above].*

**Q7. The AE can find no mention in ENWL’s SoF of alterations to network running conditions following the failure of GT1 – what consideration was given to reducing the demand on the Blackburn Group and what was the decision process that decided not to?**

A7. As noted in A4 above; following the loss of Blackburn GT1 the 33kV network was subsequently reconfigured to restore supplies to all customers. Part of this was executed automatically and the remainder by remote switching undertaken by the control centre.

In accordance with policy a contingency plan had been prepared for this scenario and under this plan the expected loadings on the 33kV circuits to the adjacent Lower Darwen Group were all within the ratings of the relevant 33kV circuits.

The Lower Darwen – Blackburn / Feniscowles 33kV circuit was expected to experience a peak demand of 288A (372A rated) and the Lower Darwen – Griffin 2 33kV circuit was expected to see a peak demand of 307A (427A rated). Following the loss of GT1 this plan was enacted and the actual loadings are shown below in A8. Whilst loadings were expected to be within the network ratings, further reduction of the group demand was achieved with the application of the 6% voltage reduction and the deployment of mobile generation in advance of the evening peak load.

Further reduction of the Blackburn Group demand was not considered necessary and was not possible with all interconnection utilised unless further mobile generation was deployed. *[AE’s note: during the discussion at the audit visit it became clear that more mobile generation had to be deployed following the failure of the 33kV fluid-filled circuit in order to avoid further interruptions to ENWL’s customers, even though the cable was re-energised with continuous pumping operative].*

Q8.

- (a) What was the loading on the following 33kV circuits; and  
 (b) What was the maximum capacity of each of these circuits during April 2013?

A8. (a) and (b) - Please see the following table:

	Immediately before GT1 failed	After the demand from Blackburn was restored	Immediately before the Lower Darwen to Griffin n° 2 failed	Maximum capacity in April 2013
Lower Darwen to Blackburn feed Feniscowles	36A	339A	189A	296A / 370A
Lower Darwen to Griffin n° 1	76A	220A	318A	340A / 427A
Lower Darwen to Griffin n° 2	77A	314A	352A	340A / 427A
Griffin to Randal St	0A	307A	347A	526A / 660A
Randal St to Blackburn feed Clarendon Rd	61A	143A	162A	279A / 350A
Randal St to Blackburn	68A	34A	62A	279A / 350A

Please note that the maximum capacity of each circuit is shown in 33kV amps, also the maximum capacity is shown as continuous rating / distribution cyclic rating. The demand is predominately cyclic.

Please also note that the flows on the above circuits were slightly higher than anticipated due to a combination of the DG within the Blackburn Group having no output immediately following the shutdown and the dead load pick-up effects.

Following restoration, a number of HV system load transfers were enacted to better balance loading between the available interconnectors, supported in some cases by temporary mobile generation.

Given the above loadings there was no cause for concern that would have driven additional load transfers. The cable circuit oil pressure readings post transfer were also stable and again gave no cause for concern.

Q9. What circuit-breakers operated when the fluid-assisted cable faulted?

A9. The Lower Darwen BSP s/s 400016 - Griffin No.2 33kVCB and the Griffin s/s 400006 - Lower Darwen No.2 33kV CB operated when the fluid-assisted cable faulted. *[AE's note: these 33kV circuit-breakers are situated at the ends of the faulted cable. These circuit-breakers were tripped when the pressure within the cable fell to the pre-set level below which it is electrically unsafe to operate the cable. Before this point there is an 'alarm' level which is designed to alert the DNO to the need to re-pressurise the circuit or to de-energise it].*

Q10. What were ENWL's priorities in restoring supplies following the failure of the 33kV fluid-filled cable?

A10. The system could not recover from the highly abnormal n-3 fault event and customer supplies were now maintained through a mixture of rota disconnection, temporary mobile generation and the remaining interconnectors.

At this stage in the event several things were happening in parallel:



- Work had started immediately after the GT1 fault to restore GT2 to service and also to remove and replace GT1.
- GT1 was replaced very quickly and energised to secure supplies on 15 May 2013. *[AE's note: given the sheer size and complexity of this task - ENWL is to be commended on the speed with which it was achieved].*
- Work began immediately to form an emergency 33kV circuit utilising the Blackburn GT2 132kV circuit and the adjacent Great Harwood T12 33kV feeder. This was aimed at providing a fourth interconnector to enable restoration of supplies whilst the emergency work continued to restore one of the two GTs at Blackburn. *[AE's note: ENWL is also to be commended on this initiative as it not only shows good engineering skill but it also amply demonstrates ENWL's commitment to provide the most secure supplies it can to its customers].*
- As demonstrated to the AE during the audit visit, work also commenced to locate and fix the cable fault. The point of failure was located and subsequently emergency pumping equipment deployed to restore the cable pressure system to allow the circuit to be temporarily restored. This enabled customer supplies to be restored; however, it meant running the system with a known faulty circuit energised.

All available transfer capacity was utilised across the event, all available measures to mitigate the risk and loss of customer supplies were deployed promptly. We consider that the use of the 132kV tower line at 33kV was highly innovative and considerably mitigated the effects on our customers.

*[AE's note: It is unusual to find a situation where a considerable leak is continuously 'fed' with cable fluid from a DNO's mobile vehicles whilst the circuit is energised. The AE considers that ENWL's decision to undertake this is a further demonstration of the way in which the security of its customers' supplies was at the forefront of the minds of its people].*

**Q11. When was the faulted cable (the n° 2 circuit) between Lower Darwen Grid Substation and Griffin Primary Substation commissioned?**

A11. The circuit has been in service since 1971. *[AE's note: during the discussions at the audit visit ENWL demonstrated that there is no known history of failures on this circuit].*

**Q12. When was this circuit last inspected?**

A12. We do not proactively inspect cable circuits. The cable section pressure readings are monitored continually by SCADA and pumping arranged as required to top up tanks or cylinders. Barrier joints pressures are alarmed as are section and tank pressures. Pumping rates are monitored across all circuits and used to identify circuits that require pro-active leak location. Joint alarms trigger an operational response as do low pressure alarms. *[AE's note: during the audit visit ENWL demonstrated its continuous monitoring of pressurised cables, the real-time values of which are displayed on its system control (SCADA) screens].*





**Q13. When were the numbers 1 and 2 circuits between Lower Darwen Grid Substation and Griffin Primary Substation last inspected?**

A13. The circuit between Lower Darwen and Griffin is a wholly underground circuit and therefore is not subject to an inspection regime, other than for the above ground section of the cable (2m) as it enters the switchgear at each end of the circuit. The cable oil pressures and hence cable integrity is continually monitored via SCADA as explained below.

Within our inspection records there is no specific record of an inspection of the cable. Details of the pumping records for the circuit will be made available during the audit visit.

It is evident that until the incident on the 30<sup>th</sup> April 2013, there had been no pumping required since December 2008. Given this history there was no reason to suspect a fault may occur on the feeder during the outage period. All indications showed the cable to be in excellent condition. *[AE's note: inspection of ENWL's records for this circuit confirms that the last pumping was carried-out on 19 December 2008 when 24 litres of fluid were added to the pressurised system].*

**Q14. What is the oil-pressure history of the numbers 1 and 2 circuits between Lower Darwen and Griffin?**

A14. Details of the pumping records for the two circuits will be made available during the audit visit. The information for the number 2 circuit is noted above and our records show that the number 1 circuit was last pumped in August 2004. *[AE's note: inspection of ENWL's records for the number 2 circuit confirms that the last pumping was carried-out on 01 August 2004 when 50 litres of fluid were added to the pressurised system].*

**Q15. What is the profile of the cable route in the oil-section that failed?**

A15. Details of the route profile for the number 1 circuit will be made available during the audit visit. *[AE's note: inspection of the profile for the faulted cable shows it to have two pressurised sections with a profile that generally falls from the Lower Darwen end to the Griffin end. The failed joint was approximately mid-way along the lower section of the profile, at a buried tank position].*

**Q16. By what means are falling oil pressures brought to the attention of ENWL's control personnel? Does this rely on an alarm contact or is there a pressure transducer constantly monitoring the pressure?**

A16. We have transducers monitoring the pressure of cable sections and tanks. These are supplemented by alarms on joint pressure sensors and on alarms derived from the transducer values. These values are displayed on the Control Engineer's screen. Should these values drop below a pre-determined value an alarm annunciates to alert the Control Engineer. These values are polled every 30 seconds by the local RTU and transmitted to the control centre within 20 seconds of any event. *[AE's note: as noted at A12 above - during the audit visit ENWL demonstrated its continuous monitoring of pressurised cables, the real-time values of which are displayed on its system control (SCADA) screens].*

**Q17. What indications regarding oil pressure are communicated to ENWL's control centre? Is the system constantly polling the alarm equipment or is it polled on the basis of a pre-determined time interval?**

A17. Please refer to the response at A16 above.



**Q18. What communication delays are inherent in oil pressure information being relayed from site to the control centre?**

A18. Alarm information is connected to our main SCADA system and is transmitted to the control centre within a maximum of 20 seconds. *[AE's note: again as noted at A12 and A16 above the 'real-time' values of each pressurised system are displayed on ENWL's system control (SCADA) screens].*

**Q19. Where was the 'band-joint' that is cited as the cause of the oil leak?**

A19. The joint which faulted was located on the junction of Vincent Street and Bolton Road in the Ewood district of Blackburn. *[AE's note: ENWL provided a plan to indicate the position of the failed joint].*

**Q20. ENWL's SoF appears to make no mention of off-loading Blackburn GSP during the outage of GT2 – please explain why this was not done?**

A20. Please see the answer at A3 above.

**Q21. The 'return to service' date in Appendix 7 of ENWL's SoF precedes the fault date and the fault date does not match the stated date of the incident – please explain?**

A21. The above is a typing error in the manually entered data report. This was identified and corrected by 3/5/13.

**Q22. What is meant by 'A' and 'B' under 'customers at risk' as shown in the tabulation in Appendix 7 of ENWL's SoF?**

A22. The A and B in the above table refer to the demand fed from section A busbar and section B busbar at Blackburn Grid respectively. Following the fault on GT1 the customers fed from Blackburn Grid were split between the two busbars with each fed via one of the interconnectors from Lower Darwen. *[AE's note: this running arrangement is shown in the schematic diagram of Figure 1 of this report].*

**Q23. Does the new GT2 transformer at Blackburn Grid have the same type of tap-changer as the faulted one on GT1? If so, what specific on-site checks were carried-out to ensure it did not have the same defect before it was put on load?**

A23. The tap changer is of an identical type and we have included details of similar units on our system in Appendix 11 of our SoF. As per the report submitted from the manufacturer the fault was due to an incorrectly tightened connection. All other units have been inspected via endoscope to confirm there are no defects. No other defects of this type have been found in ENWL.

Dates of all checks can be provided if required. The manufacturer has subsequently changed the assembly process to prevent similar occurrences. The defect occurred on a specific batch of transformers when the manufacturer moved from a manual bolt torque assembly method to an automated bolt assembly technique. The technique failed to count the number of revolutions of the bolt before the torque setting was achieved. The connection in question became cross threaded resulting in the automated torque wrench attaining the require setting but not tightening the two components adequately. *[AE's note: Appendix 11 of ENWL's SoF lists seventeen similar 132/33kV Grid Transformers which ENWL has on circuit. The tap-changer is situated within the main tank of this type of transformer.]*



**AE's note (continued):** ENWL is commended for having devised and used a method whereby the potentially suspect connections can be reliably inspected within a relatively short period of time; hence safeguarding its customers from incidents due to the identified cause of the failure of GT1 at Blackburn Grid Substation].

**Q24. What learning points has ENWL incorporated into its procedures as a result of this event?**

A24. In responding to the n-3 event, we utilised one of the 132kV lines to cross connect to a 33kV feeder and hence form a temporary additional in-feed into the group. This technique has now been incorporated into our pre-outage considerations on major works and has been deployed on a number of GT changes such as Ulverston to improve network resilience to non-credible events. This contingency includes pre-purchase and pre-positioning of the required materials. With the exception of this change no other specific items of learning were identified.

**Q25. What further learning points should be considered as a result of the application of the current one-off Exceptional Event Claims process?**

A25. During periods of severe system depletion, operationally related events may be separated in time by more than a few hours. For example following an exceptional event supplies may be restored by a combination of DG and interconnection. However whilst this may meet the initial demand it may not be sufficient to meet the peak demand or indeed sustain the demand if the DG ceased output due to, say, low wind speed. Such scenarios are, in our view, one continuous event.

68. ENWL also provided further information both during and subsequent to the audit visit. This includes:

- Information to show that the affected section of ENWL's network is P2/6 compliant;
- Information to show that the failure of the number 1 Grid Transformer at ENWL's Blackburn Grid Substation was due to a manufacturing defect;
- Information to show that, prior to the current incident, ENWL's number 2 33kV circuit from Darwen Grid Substation to Griffin Primary Substation has been free from incidents due to this cause;
- \*ENWL's photographs of the failed tap-changer connections (taken at the manufacturer's works in Germany);
- ENWL's photographs of the failed fluid-filled cable joint;
- The disposition of the temporary mobile generation across the various HV networks affected by this incident;
- ENWL's control room log for this event;
- ENWL's incident reports from which it calculated the CI and CML attributed to this event;
- The details of ENWL's SCADA alarms received during this event;
- A representation of the event on ENWL's SCADA system;
- Copies of ENWL's protection schemes and associated relay settings for its 132kV and 33kV feeders affected by this event; and
- A discussion of ENWL's learning points following this incident, including any subsequent preventative measures applied to its system.



## 4. Audit part 2

### 4.1 ENWL's performance in preventing the event

69. In viewing ENWL's performance in preventing this Incident, the AE has considered what more ENWL could have reasonably been expected to have done to ensure that its number 1 132/33kV Grid Transformer at its Blackburn Grid Substation was free from defects and that its number 2 33kV circuit from Lower Darwen Grid Substation to Griffin Primary Substation was sound.
70. This is particularly relevant as ENWL has no records of problems with its similar 132/33 Grid Transformers or, with its continuous monitoring, any reason to suspect the integrity of the fluid-filled cable.
71. After extensive investigation by the manufacturer, the failure of the Grid Transformer was found to be a manufacturing defect and not within ENWL's control.
72. Also, the faulted 33kV fluid-filled cable had no history of similar problems and, consistent with best international practice, the pressurised system was being monitored in 'real-time' by ENWL's SCADA equipment.
73. ENWL's measurement systems clearly show the tripping of the number 1 132/33kV Grid Transformer at its Blackburn Grid at 07:41 on 30 April 2014.
74. ENWL's measurement systems also show the restoration of supplies by a combination of the operation of its automated switching equipment and tele-controlled switching by its control engineer.
75. The consequent on-going switching to balance the system and maintain its stability are also recorded, as is the failure of the 33kV fluid-filled cable and the further loss of supplies at 17:35 as the evening peak demand grew.
76. ENWL's measurement systems show how its control engineers managed to restore most of its customers' supplies from its severely depleted distribution system, and how the deployment of further temporary mobile generation together with the continuation of the 6% voltage reduction enabled ENWL to avoid having to deliberately disconnect any of its customers.
77. The AE considers that there is nothing else that ENWL could have done to prevent this event from occurring.

### 4.2 ENWL's performance in mitigating the effects of the event

78. ENWL's sequence of photographs taken during the investigation at the manufacturer's works and included with its SoF show the internal damage caused to the Grid Transformer by the manufacturing defect. As an example, Photograph 1 of this report shows the damage to the internal connections of the failed Grid Transformer.
79. ENWL's photograph 2 of the ruptured outer casing of the 33kV joint sleeve that failed demonstrates how much fluid must have been lost from the pressurised system at the time of the failure. The AE notes from the circuit records that the failed joint was at a pressurised tank position within the Griffin section of the cable route. This section is pressurised by three tanks with a total capacity of 735 litres which would have 'fed' the leak before the circuit faulted.
80. Furthermore, during the time that ENWL re-energised this circuit to ensure that it did not need to deliberately disconnect its customers; ENWL's records show that its mobile pumping equipment used 4,300 litres of fluid to maintain the electrical integrity of the circuit.



81. The re-energisation of the faulted 33kV circuit, together with the deployment of temporary mobile generation and the application of a 6% voltage reduction enabled ENWL to maintain the supplies to all its customers as a pro-active alternative to having to impose rotational allocation of supplies.
82. ENWL's initiative to energise the idle 132kV circuit at 33kV into its Blackburn Grid Substation to provide enhanced system security for its customers is considered to be particularly commendable.
83. An examination of ENWL's measurement systems and a SCADA representation of its distribution network confirm that ENWL did all it could to restore supplies as expeditiously as possible.
84. The AE has studied the running arrangements of ENWL's 132/33/6.6kV distribution network affected by this event and concludes that ENWL's protection systems worked correctly to clear the incidents from ENWL's distribution system.
85. The AE commends ENWL's engineering team for the decision to re-energise the faulted 33kV fluid-filled cable and the deployment of temporary mobile generation to meet the peak demand on the system and so avoid the need to deliberately disconnect its customers.
86. The AE also commends ENWL's control engineers for analysing the situation, and for restoring supplies as rapidly as possible, thereby minimising the duration of the interruptions to ENWL's customers.
87. The AE is aware of the changes in the loading that occurred during the course of the event and commends ENWL's control engineers for their diligence in monitoring the situation and in using tele-controlled switching on ENWL's 6.6kV network to optimise the situation and keep the 33kV system stable.
88. The action that ENWL has taken to inspect its similar 132/33kV Grid Transformers is also considered to be commendable and a good example of a DNO learning from a known event and doing its best to prevent a re-occurrence.

#### 4.3 Recommended performance adjustments

89. The AE's recommendations to Ofgem are shown in Table 3.

**Table 3 – Recommended performance adjustments**

	<b>Amount above threshold</b>	<b>Audit part 2 recommendation</b>
<b>CI</b>	0.39	0.39
<b>CML</b>	0.00	0.00

#### 4.4 Detailed justification

90. In reaching a judgement on a recommendation, the AE has firstly considered whether or not ENWL could have reasonably taken any different course of action that would have prevented the manufacturing defect in the Grid Transformer or the latent defect in the 33kV fluid-filled cable.
91. In viewing ENWL's performance in preventing this event, the AE has taken into account his personal knowledge of the United Kingdom's distribution system practice and that of his colleagues who have considerable operational experience of incidents due to many causes.





92. In commending ENWL for restoring its customers' supplies as expeditiously as possible, the AE is conscious of the difficulties it faced with the over-lapping incidents whilst avoiding the need to deliberately disconnect any supplies.
93. The AE notes ENWL's actions in inspecting its similar Grid Transformers and is pleased to learn that all seventeen have been found to be free from this particular manufacturing defect.
94. Regarding the failure of the 33kV fluid-filled cable joint, the AE considers that ENWL's approach to constantly monitoring the values of all its pressurised cable systems is amongst the best international practice that he has seen.
95. The AE is therefore satisfied that ENWL had no cause to doubt the integrity of either its Grid Transformer or its 33kV cable.
96. In considering ENWL's restoration strategy, the AE is conscious that ENWL's sophisticated automated switching equipment together with the commendable skill and speed of its duty control engineer in analysing the SCADA alarms and indications generated by this event, enabled ENWL to restore its customers' supplies as rapidly as possible.
97. The AE is satisfied that ENWL's distribution network at Blackburn Grid Substation complies with the requirements of Security of Supply Standard P2/6 (52.3 MVA firm demand).
98. The AE therefore concludes that ENWL's claim is justified and recommends to Ofgem that the amount of CI above the threshold value should be excluded from ENWL's performance for reporting year 2013/14.
99. As noted above, the AE has discussed ENWL's learning from this incident and is pleased that ENWL has confirmed that its other, similar 132/33kV Grid Transformers are free from this defect, enabling ENWL to consider the manufacturer's conclusion that the failure of the number 1 Grid Transformer at ENWL's Blackburn Grid Substation was a 'one-off' manufacturing defect.



## Appendix A - Record of Audit part 1

Table A-1: Appointed Examiner's Information Log

"One-Off" Exceptional Event	Reporting Year 2013/14
Licensed Area	ENWL
Date of event	30 April 2013
Cause	Internal failure of a 132/33kV Grid Transformer and the failure of a fluid-filled 33kV cable joint
Notification to Ofgem	02 May 2013
SoF received	29 July 2013
SoF information	<ul style="list-style-type: none"> <li>• The n° 1 132/33kV Grid Transformer failed due to a manufacturing defect within its tap-change equipment;</li> <li>• At the time of this failure the number 2 circuit was under an outage to replace the other Grid Transformer;</li> <li>• Thus at the time of the incident Blackburn Grid was on a single 132kV circuit infeed;</li> <li>• At 07:41 on Tuesday 30 April 2013 the 33kV and the 132kV circuit-breakers tripped, de-energising GT1;</li> <li>• System automation restored 12,450 customers within three minutes and ENWL's control engineer restored the remaining 14,021 from alternative sources using tele-controlled switching;</li> <li>• To achieve the above, the 33kV network had to be 'split' to optimise the load balance and hence stabilise the system;</li> <li>• A 6% voltage reduction was applied and mobile generation was deployed to help manage the system loading;</li> <li>• A constant watch was kept on system loading and network alterations were made on the 6.6kV network to further balance the system;</li> <li>• During the evening peak load one of the 33kV circuits being used to backfeed Blackburn Grid failed, resulting in the system being unable to meet the demand and 21,907 of ENWL's customers lost supply;</li> <li>• A further 34,238 customers were restored within three minutes by a combination of ENWL's automated switching system and ENWL's control engineer using tele-controlled switching;</li> <li>• Further mobile generation was deployed, the 6% voltage reduction was continued and the decision was taken to re-energise the faulted fluid-filled cable whilst maintaining the pressurised system using ENWL's mobile equipment – thus avoiding deliberate disconnections;</li> <li>• ENWL also took the initiative to utilise the idle 132kV circuit associated with the number 2 Grid Transformer at Blackburn Grid and run it at 33kV from an adjacent load group to provide relief to the severely depleted Blackburn Group;</li> </ul>



	<ul style="list-style-type: none"> <li>• Having energised this temporary 33kV infeed, the faulted fluid-filled cable was de-energised, the leak located and repaired and the circuit returned to normal service;</li> <li>• The failed transformer was removed from its plinth and taken to the manufacturer's factory in Germany for examination;</li> <li>• The transformer destined for the number 2 position was used to replace the faulted unit;</li> <li>• The manufacturers determined that it was a one-off manufacturing defect that caused the transformer to fail;</li> <li>• ENWL has checked all its similar transformers and found them to be clear of this problem; and</li> <li>• ENWL increased the pace of work to replace the number 2 Grid Transformer at Blackburn Grid.</li> </ul>
<b>Additional pre-visit information provided</b>	Based on the SoF the AE drew up a list of initial questions. These were discussed during the audit visit. This initial list of questions, together with ENWL's responses, is contained in paragraph 67 of the report.
<b>Location of audit visit</b>	ENWL's Manchester Control Centre
<b>Date of audit visit</b>	29 September 2014
<b>Visiting Auditor</b>	Geoff Stott (ep)
<b>ENWL's Representatives</b>	Steve Cox, Chris Fox and Tony Pointon
<b>Information provided during and subsequent to the audit visit</b>	<p>Comprehensive documentation / information including:</p> <ul style="list-style-type: none"> <li>• A discussion of the protection arrangements applied to the affected sections of ENWL's distribution system;</li> <li>• The settings applied to the above protection schemes;</li> <li>• A discussion of the tripping of the circuit-breakers for both incidents and the actions of ENWL's automated switching system in restoring supplies within three minutes;</li> <li>• A discussion of the temporary arrangements that ENWL had to put in place to maintain a balanced and stable system;</li> <li>• Sight of ENWL's switching programmes for the event;</li> <li>• Copies of the relevant 132kV, 33kV and 6.6kV SLDs;</li> <li>• Sight of the printout from ENWL's SCADA system that shows the alarms generated by the event;</li> <li>• Sight of ENWL's incident reports that show: <ul style="list-style-type: none"> <li>◦ the number of customers affected by the incident to be 35,211; and</li> <li>◦ the customer minutes lost due to the incident to be 964,554;</li> </ul> </li> <li>• The AE confirms that these figures agree with those quoted in ENWL's SoF;</li> <li>• Using ENWL's total connected customers at 30 September 2013 of 2,371,790 the number of customers affected equates to a CI of 1.485 <math>[35,211 \times 100 / 2,371,790]</math>;</li> </ul>





	<ul style="list-style-type: none"> <li>• Similarly, the customer minutes lost for this event equate to a CML of 0.407 [964,554/2,371,790];</li> <li>• ENWL's photographs taken during the manufacturer's investigation in Germany and ENWL's photographs of the faulted 33kV fluid-filled joint;</li> <li>• The profile of the cable route and the location of the faulted joint along it;</li> <li>• Discussed post-fault learning points, including what ENWL's approach had been to the other seventeen Grid Transformers of the same type that it has on circuit;</li> <li>• Confirmed P2/6 compliant (52.3 MVA firm on 2x90 t/fs);</li> <li>• ENWL provided answers to the initial questions plus additional information both during and subsequent to the audit visit; and</li> <li>• Okay regarding compliance with Appendix 4 of Paragraph 8.58 of CRC 8.</li> </ul>
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**Table A-2: Impact on CI and CML**

	CI		CML	
Voltage (DNO's incident reference)	Claimed	Audited	Claimed	Audited
132kV (kV - 41/00011)	0.591	0.591	0.070	0.070
EHV (EHV - 45/006025)	0.893	0.893	0.336	0.336
HV	0	0	0	0
LV	0	0	0	0
Total	1.49	1.49	0.41	0.41
ENWL Threshold (total)	1.10		0.80	
Part 1 Exceptionality Test	Pass		Fail	
Part 1 Precondition of eligibility (meets App 3 to paragraph 8.57 of CRC 8)	Pass			

**General note:** ENWL's measurement systems are subject to QoS audits for accuracy of reporting and it is not within the AE's ToR to repeat that work as part of the examination of exceptional event claims, although any consequential adjustments to reporting accuracy will be reflected in Ofgem's final adjudication of reported performance for the regulatory reporting year 2013/14.



## Appendix B - ENWL's photograph

Photograph 1 – The failed tapping lead weld resulting from the manufacturing defect within the tap-changer of GT1 at Blackburn Grid





Photograph 2 – The ruptured casing of the failed joint of the 33kV fluid-filled cable

