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**Appointed examiner's audit of One-Off Exceptional Event Claim  
Western Power Distribution (West Midlands)  
Failure of GT1 at Lichfield Primary Substation  
02 December 2015**

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Name	Position	Signed	Date
Geoff Stott	Ofgem's Appointed Examiner		10 June 2016

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## Glossary

Abbreviation	Meaning
AE	Appointed Examiner
CB	Circuit-breaker
CI	Customer Interruptions per 100 connected customers
CML	Customer Minutes Lost per connected customer
DNO	Distribution Network Operator
ep	energypeople
NEDeRS®	The UK's National Equipment Defect Reporting Scheme
OLTC	On Load Tap Changer
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
WPD	Western Power Distribution
WPD(WM)	Western Power Distribution's West Midlands licensed area

### 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 Western Power Distribution (WPD) under the “one off” exceptional event mechanism that an incident which affected its number 1 132/11/11kV transformer at its Lichfield Primary Substation at 19:54 on Wednesday 02 December 2015 adversely affected the reported performance for its West Midlands Networks WPD(WM) licensed area for the regulatory reporting year 2015/16.
2. The AE has visited WPD 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 both CI and CML.
3. The AE concludes that the event falls within the category of an “other event” as defined in paragraph 2D.34 of Special Licence Condition CRC 2D, including meeting the exceptionality requirements set out in Appendix 3 thereof.
4. The AE therefore proceeded to part 2 of the “one-off” exceptional event process, assessing WPD’s performance in mitigating the impact of the event upon its customers.
5. The AE concludes that WPD’s routine inspection and maintenance programme for its grid transformers and associated tap-changers is consistent with good practice and was up to date at the time of the incident.
6. The AE also concludes that, prior to this incident, WPD had done all it could to ensure its number 1 132/11/11kV transformer and associated tap-changer at its Lichfield Primary Substation were free from defects.
7. Following the AE’s examination of the tripping of WPD’s Rugeley Hospital 11kV circuit-breaker and the subsequent information provided by WPD, the AE is satisfied that WPD had done all it could to ensure this equipment and its associated protection was free from any known defects.
8. The AE commends WPD’s control engineers for analysing the alarms generated by the incident and for restoring all supplies as quickly as possible from what had become a depleted 11kV network connected to its Lichfield Primary substation.
9. The AE particularly commends WPD for arranging for a replacement 132/11/11kV transformer to be shipped from Europe and to be installed and commissioned within eighteen days of the incident occurring.
10. The AE therefore concludes that WPD has met the criteria of Appendix 4 to paragraph 2D.35 of Special Licence Condition CRC 2D and that the incident is therefore deemed to be eligible for adjustment in the DNO’s reported performance.
11. The AE recommends that an adjustment to WPD(WM)’s 2015/16 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	1.06	0.05	0.05
CML	1.89	1.08	1.08

## 1. Audit part 1

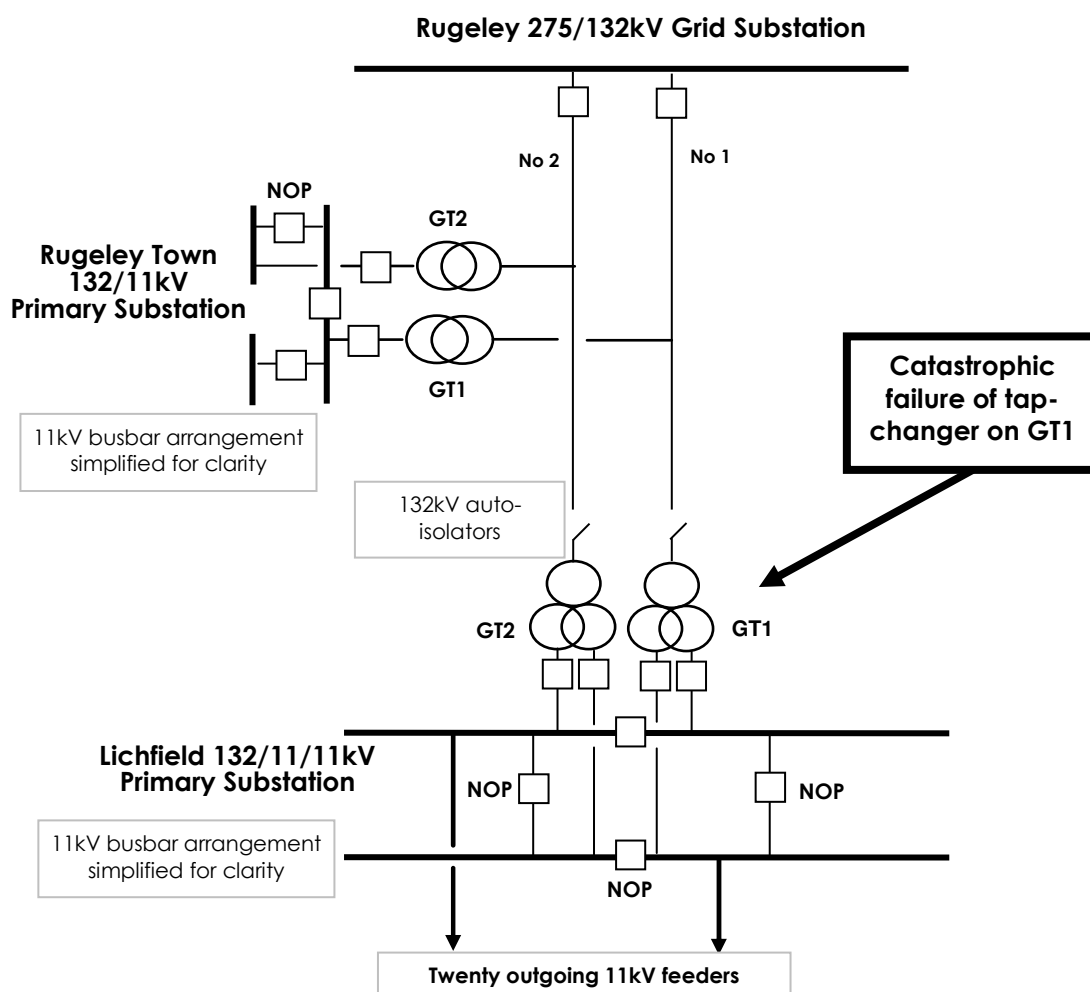
### 1.1 Summary of the main facts

12. 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.
13. The two 132kV infeeds to WPD's Lichfield Primary Substation emanate from its Rugeley 132kV Grid Substation. Both 132kV circuits are teed to provide 132kV infeeds to its Rugeley Town Primary Substation. At the time of the incident WPD's affected network was running normally.
14. WPD has provided evidence to support its claim that a catastrophic failure within the tap-changer associated with its number 1 132/11/11kV transformer at its Lichfield Grid Substation resulted in the insulating oil within the transformer catching fire.
15. At 19:54 on Wednesday, 02 December 2015 WPD's protection operated correctly to de-energise the affected 132kV circuit, auto-isolate the faulted transformer and restore the 132kV infeed to its number 1 132/11kV transformer at its Rugeley Town Primary Substation.
16. WPD's sequence-closing schemes operated to restore all affected supplies within three minutes with the exception of its customers supplied via the Rugeley Hospital 11kV circuit-breaker at its Rugeley Town Primary Substation as the circuit-breaker tripped at the time WPD's auto-close sequence switching closed the 11kV bus-coupler circuit-breaker.
17. The ferocity of the fire at Lichfield Primary Substation necessitated the attendance of the local fire service. In order to tackle the blaze safely, the fire service requested that the number 2 132/11/11kV transformer at WPD's Lichfield Primary Substation be de-energised.
18. Prior to de-energising the number 2 132kV infeed, WPD transferred all the load to the number 1 132kV infeed at its Rugeley Town Primary Substations thus safeguarding these customers from a second supply interruption
19. In order to comply with the request from the fire service, the number 2 132kV infeed to WPD's Lichfield Primary Substation was de-energised at 21:25 on 02 December 2015, affecting the supplies to its 25,117 customers supplied via the twenty 11kV feeders emanating from that site.
20. WPD had to 'stretch' its 11kV distribution network to restore as many of its customers as possible, resorting to trimming loads across 'donor' circuits and back-feeding some distribution substations at the low-voltage level.
21. 36 mobile generators were also deployed, enabling WPD to restore all supplies by 05:02 on 03 December 2015.
22. It was found that the fire had damaged the auxiliary cables associated with the number 2 132/11/11kV transformer at Lichfield Primary Substation and temporary protection arrangements had to be put in place before it could be re-energised. This was achieved by 04:33 on 03 December 2015 when GT2 at WPD's Lichfield Primary Substation was re-energised, assisting WPD to restore some supplies more rapidly than switching activity on alternative 11kV feeders.
23. In view of the temporary protection arrangements, WPD installed a 25 metre exclusion / safety zone around GT2 until such time as the full protection arrangements could be re-established.



24. Meanwhile, as reported in WPD's SoF, believing that the 11kV Rugeley Hospital circuit-breaker at Rugeley Town Primary Substation had tripped due to a fault, WPD carried-out switching operations along this feeder, re-energising it section by section so as to avoid further interruptions to its customers.
25. Two sections of underground cable along this feeder were left de-energised, subsequently pressure-tested with no faults found and restored to service.
26. GT2's protection was restored to normal at 24:00 on 03 December 2015 and the exclusion / safety zone around it was removed.
27. However, as GT2 is a 'sister' unit to the faulted GT1, WPD left GT2 on fixed taps until such time as the components in its tap-changer could be examined for any signs of abnormality.
28. WPD sourced a replacement 132/11/11kV transformer from Europe, shipped it to Lichfield Primary Substation, installed and commissioned it within eighteen days of the incident.
29. The replacement transformer was energised at 18:49 on 20 December 2015 and put on load at 20:13 that night.
30. The commissioning of the replacement transformer enabled WPD to carry-out a detailed examination of the tap-changer associated with its number 2 132/11/11kV transformer at its Lichfield Primary Substation when signs of abnormal overheating were noted.
31. WPD intends to replace the contacts that are showing signs of overheating and has contacted General Electric (GE), the owners of the patents; a reply being anticipated by 20 May 2016.
32. WPD has nine more transformers fitted with the same type of tap-changer as the one that failed and is in the process of arranging outages to inspect them, including taking oil samples for dissolved gas analysis. WPD reports that this work is on target to be completed by end July 2016.
33. A simplified view of the section of WPD's distribution system affected by this event is shown in Figure 1.

**Figure 1 – Simplified Network Diagram of WPD's distribution system affected by the incident**



**Notes:**

1. Only the salient items of switchgear are shown.
2. "NOP" denotes 'normal open point'.
3. WPD's network was running normally at the time of the incident.
4. Apart from the Rugeley Hospital 11kV feeder out of Rugeley Town 132/11kV Primary Substation, all supplies were restored within three minutes following the initial clearance of the incident by the correct operation of WPD's protection and auto-close sequence schemes.
5. All supplies from Lichfield 132/11/11kV Primary Substation were interrupted following the subsequent de-energisation of the number 2 132kV feeder in compliance with the request from the fire service.



## 2. Exceptionality requirements

### 2.1 Does the event qualify for exclusion?

34. The AE considers that the event falls within the category of an “other event” as defined in paragraph 2D.34 of Special Licence Condition CRC 2D, and meets the exceptionality requirements set out in Appendix 3 thereof.
35. The AE therefore considers that, subject to satisfying the requirements of Appendix 4 to paragraph 2D.35 of Special Licence Condition CRC 2D, the event qualifies for possible exclusion under the “one-off” exceptional events process.

### 2.2 Exceptionality test results

36. 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	0	0
HV	0	0
LV	0	0
<b>Total</b>	<b>1</b>	<b>1</b>

37. 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
CI exceptionality	1.01	1.06	1.06	pass	0.05
CML exceptionality	0.81	1.89	1.89	pass	1.08

**Notes:**

1. Ofgem's CI and CML exceptionality criteria are set out in the AE's ToR<sup>1</sup>.
2. The audited CI and CML used in the exceptionality test have been determined from the number of incidents attributed to the event.
3. 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 the DNO's performance.
4. 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 2015/16 to 2018/19

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

#### 3.1 Dealing with the incident

38. WPD's Lichfield Primary Substation is fed from its Rugeley 132kV Grid Substation via two 132kV feeders that also feed its Rugeley Town Primary Substation via feed connections.
39. WPD's 11kV switchboard at its Lichfield Primary Substation is a double busbar arrangement fed via the double-wound 11kV secondary windings of its two 132/11/11kV transformers.
40. The double busbars are equipped with both bus-section and bus-coupler circuit-breakers with a sequence-close system that automatically operates to restore customers' supplies in the event of the loss of one of the incoming 132kV feeders.
41. The 132/11kV transformers at WPD's Rugeley Town Primary Substation have single secondary windings which feed the local double-busbar 11kV switchboard. This is also fitted with a sequence-close system that automatically restores supplies in the event of the loss of one of the incoming 132kV feeders.
42. Hence, as a result to the fire, when WPD's protection operated to de-energise the number 1 132/11/11kV transformer at Lichfield Primary Substation, the above sequence-close systems operated to restore customers' supplies by automatically switching them to the number 2 132kV incoming feeders at both Lichfield and Rugeley Town Primary Substations.
43. WPD considers that its protection operated correctly to clear the 132kV incident from its distribution network and to restore its customers' supplies within three minutes.
44. One exception to these short-interruptions affected the 898 customers supplied via WPD's Rugeley Hospital 11kV feeder from its Rugeley Town Primary Substation.
45. In this instance the 11kV source circuit-breaker had tripped at the time the sequence-close scheme had automatically operated to close the normally-open 11kV bus-coupler circuit-breaker.
46. Believing this to be as a result of an 11kV fault, WPD restored the feeder section by section to determine if a fault existed or not, pressure-testing two separate sections of the feeder, determining that no 11kV fault existed and re-energising them.
47. Following the complete restoration of this feeder with no fault found, WPD carried-out extensive tests on both the circuit-breaker itself and its protection equipment and found no problem with either. The physical separation of this circuit-breaker from the bus-coupler circuit-breaker rules out the possibility of vibration causing the spurious tripping.
48. As noted above, before the number 2 132kV feeder was de-energised, WPD's contingency switching had previously moved all the load at its Rugeley Town Primary Substation to the number 1 incoming 132kV feeder.

49. Thus, at 21:25 on Wednesday 02 December 2015 in response to the request from the fire service, when the number 2 132kV infeed to both Lichfield and Rugeley Town Primary Substations was de-energised, supplies to WPD's customers fed from Rugeley Town Primary Substation were unaffected whilst those fed from Lichfield Primary Substation lost supply.
50. WPD considers that its duty control engineers reacted well in assessing the alarms generated by the event and despatching its personnel to site as a matter of urgency.
51. WPD also considers that its control engineers acted correctly in response to the request from the fire service in carrying-out the contingency switching at Rugeley Town Primary Substation before de-energising the number 2 132kV infeeds to both Lichfield and Rugeley Town Primary Substations.
52. Following this de-energisation, WPD further considers that its personnel reacted well to the differing challenges regarding the restoration of its customers' supplies (i.e. the fire in GT1, the effects of this on the protection of GT2 and the restoration of the Rugeley Hospital 11kV feeder).
53. Furthermore, WPD commends all those involved in the removal of the damaged transformer, the sourcing and shipping of a replacement unit and its subsequent installation, commissioning and putting on load at 20:13 on 20 December 2015, only 18 days after the incident.
54. Following the incident, WPD commissioned a third-party forensic investigation into its cause in an attempt to determine if this is a one-off failure or indicative of a design fault with this type of tap-changer, of which it has several other units of varying age.

### 3.2 WPD's answers to questions on its performance

55. Within the last two years, the AE has reviewed WPD's design standards, construction methods and maintenance procedures during previous visits to audit exceptional event claims and found them fit for purpose.
  56. The AE confirms that WPD's emergency procedures provide for the type of event being examined here.
  57. To aid understanding of the background to WPD'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 WPD's claim.
  58. The initial questions were discussed during the AE's visit to WPD's control centre on 10 May 2016, when the records of WPD's SCADA system, the incident report and other information were made available.
  59. WPD 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 WPD's answers being printed in normal font.
- Q1. What, if any, changes has WPD made to its emergency plans and procedures since the Appointed Examiner (AE) last visited to audit the one-off exceptional event (OOEE) claim concerning the incident affecting WPD's 66kV system in the Evesham area that occurred on 16 July 2014?**
- A1. WPD has made several changes since the AE's last visit. For clarity, these are grouped under three headings as follows:

## Control

Implementation of OMS (Outage Management System) throughout all of Western Power. A new system has now gone live which enables all engineers to view all of the outages in their area and quickly identify risks and any potential outage clashes before they are even at the request stage.

Primary Contingency Full Reviews of all primary substations which identify any potential shortfalls

Sequence switching scheme reviews - Including all 11kV Transformers and Delayed Auto Reclose schemes, in order to achieve quicker customer restoration and network security

Sequence Switching (SQC) Scheme Implementations using the PowerOn Network Control System. Intelligent software driven replacements of old hardwired site schemes that give greater flexibility and are able to restore customers under different scenarios.

## Emergency Planning

WPD has recently carried out emergency services briefings. These briefings were designed to address a number of topics.

Clarification of what WPD's equipment is out on the network. A typical example of this would be BT poles versus WPD poles for electrical distribution.

Discussions took place regarding potential inconsistencies amongst the emergency services across WPD's licence areas. This included the ability to get adequate information from the emergency services regarding the site location and the equipment involved when they are reporting an incident.

Included in the discussions were also:

- Lines low / down;
- Proximity working / safety clearances; and
- Safe access to WPD's sites.

WPD is now working with the emergency services to create a bespoke training package which WPD will deliver to the local category 1 responders (Blue lights). To support this WPD is also updating its own emergency services guidance documents.

Following this, WPD is creating a new direct number to enable the emergency services to contact WPD's Dispatch directly (change of process). This will enable the call to be flagged as a high priority and handled accordingly by a team leader.

As a category 2 responder under the civil contingences act (2004), WPD continues to actively engage with the Local Resilience Fora.

A large part of this work includes the promotion of the Priority Services Register (PSR) for all of our vulnerable customers. One of the outputs will provide an accurate and up to date list of all priority customers who are supplied from any given WPD asset. This will include grid references for all properties to aid the mapping that is used by local authorities and emergency responders.

## Projects

Spare transformers: Upton Warren Storage Site there is a selection of 132kV transformers of various vector groups and impedances that cover 95% of WPD's Midlands fleet. For 33kV & 66 kV transformers there are around 30 available units held in storage at a local manufacturer.

The transformer which WPD used to replace GT1 at Lichfield Grid Substation was sourced through this channel and was originally destined for an asset replacement scheme at WPD's Solihull Substation.

The unit was manufactured in Austria. The contract T&C's with the supplier has since been modified to consider emergency situations such as WPD faced at its Lichfield Grid Substation.

Pre-outage risk assessments: Prior to any primary related outage, a detailed pre-outage risk assessment is undertaken. This incorporates a check of linear assets such as helicopter line patrols and fluid filled cable gauge readings and health checks.

Substation assets: Partial discharge testing of switchgear and checking of pressure & fluid readings are undertaken.

**Q2. When was GT1 and its associated tap-changer at Lichfield Grid Substation commissioned?**

A2. 1971.

**Q3. What make and type is the faulted tap-changer?**

A3. English Electric FDD.

**Q4. What is WPD's experience of the reliability of this type of tap-changer?**

A4. Until this incident the English Electric FDD has been a reliable tap-changer. WPD's failure records and modification documents have been interrogated and there are no reported instances or issues with this type of tap-changer.

**Q5. What is the UK's reported experience of the reliability of this type of tap-changer as reported via the ENA's National Equipment Defect Reporting Scheme (NEDeRS®)?**

A5. The AE was shown a download from the NEDeRS database. This shows no reported national incidents, defects or dangerous incidents against this type of tap-changer. *[AE's note: the AE can confirm that there are no entries on this download relating to the English Electric FDD tap-changer].*

**Q6. What is WPD's policy for the routine maintenance of this type of tap-changer?**

A6. The company's maintenance policy is predominantly based on a time based frequency with the diverter set at 3 yearly intervals and the selector every 6 years.

**Q7. On what is WPD maintenance policy based – e.g. manufacturers recommendations or industry experience?**

A7. WPD's Policy is based upon manufacturer's recommendations for what to complete during the maintenance together with the industry's experience for the intervals of when to maintain. Periodically the 'as found' sheets, defects and failure rates are checked and a review of the time intervals is undertaken to make sure that they are still appropriate.

**Q8. WPD's SoF contains the most recent records for the maintenance and inspection of the faulted tap-changer. During the audit visit, WPD is asked to provide information as to what precise operations are involved in carrying-out the various activities listed in its SoF.**

A8. WPD provided a full explanation of the operations it carries out for each of the activities listed in its SoF.

*[AE's note: the AE can confirm that WPD provided a full explanation of the activities listed in its SoF. The AE is satisfied that WPD's tap-changer inspection and maintenance is both comprehensive and fit for purpose].*

**Q9. What was the reasoning behind WPD carrying-out the partial discharge tests shown as being completed on 01 September 2015?**



A9. These were completed as part of the routine substation inspections and are completed on the 11kV switchgear to ensure that the switchboard is discharge-free and safe for operation. The record of the inspection is listed against every asset when viewing WPD's 'CROWN' database. The testing shown in WPD's SoF was specifically in relation to the 11kV switchboard.

**Q.10. Does GT2 at Lichfield Primary Substation have the same type of tap-changer as the faulted one on GT1? If so, what specific on-site checks have been carried-out to ensure it does not have the same potential defect?**

A10. GT2 has the same type of tap-changer; an English Electric FDD. GT2 has been shut-down and on-site checks have been undertaken. These included the removal of the oil and a sample was sent to TJH2B for sampling. The oil tests confirm that overheating is apparent in the selector tank.

The covers were removed which showed carbon deposits in the remaining oil and on internal surfaces. Fixed contacts had excessive pitting/burning on them which is not normal. The contact wipe was normal and the mechanism seemed to be working satisfactorily. These results have shown that the unit is suffering from overheating and explain the carbon in the oil.

GT2 at Lichfield Primary Substation has been left on fixed tap pending further investigation and consultation with tap-changer specialists.

WPD was concerned about the apparent discharge tracking on one of the through-bushings from the diverter, which may have happened due to the build-up of carbon in the oil.

The diverter was therefore opened and the resistors were all found to be in good condition. The diverter contacts all had wear left on them and would have lasted until the next maintenance.

There are a further 9 tap changers of this type within WPD. These will be checked to make sure that there is no overheating and no play in the mechanism. During the checks a decision will be made on the need to change the gear wheels if there is too much play in the mechanism.

A company-wide modification has been issued for the inspection of the remaining units where an oil sample will be taken to confirm that there are no signs of overheating or movement in the mechanism.

WPD is currently awaiting GE (owner of the tap-changer drawings and designs) to find the relevant drawings and produce a quote for the replacement parts. This is anticipated to be with WPD by w/e 20th May 2016.

If signs of overheating are found in the other units, the tap-changers will be placed on fixed tap until the relevant parts can be obtained to rectify the situation.

If signs of movement in the mechanism are present, again the units will be placed on fixed tap until this can be rectified.

If the oil is clear and there is no movement in the mechanism, the units will be placed back into service.

A NEDeR has been raised for the failure of GT1 and issued to the industry under reference number 2016/0025/00.

Historically the 9 units of this type have been in service for up to 40 years without any previous failures.

The decision to place the second unit on fixed tap at Lichfield was purely based on a site-specific risk assessment of the unit being a “sister” to the one that failed.

**Q11. Given that WPD’s SoF indicates that GT2 at Lichfield Primary Substation was de-energised as a result of an emergency service request, what, if any, contingency switching was carried-out prior to GT2 being de-energised?**

A11. Immediately following the “Emergency Disconnection Request” of GT2 at Lichfield Primary Substation, WPD’s control engineers secured customers’ supplies at Rugeley Town 132/11kV Primary Substation by closing the 11kV bus- coupler circuit-breaker and opening GT2’s 11kV circuit-breaker. This transferred all supplies onto GT1 Rugeley Town Primary Substation, restricting the further customer interruptions to Lichfield Primary.

**Q12. WPD’s SoF indicates that customers supplied via the Rugeley Hospital feeder out of its Rugeley Town were off supply for longer than other customers supplied from this Primary Substation. What was the reason for this?**

A12. The Rugeley Hospital 11kV circuit-breaker tripped when the 11kV bus-coupler circuit-breaker auto-closed via sequence switching to restore the 11kV busbar when the number 1 132kV infeed tripped due to the incident affecting GT1 at Lichfield Primary Substation.

WPD’s systems show the following timings:

19:58:04.418 Rugeley Town 11kV Bus Coupler Section W, 11kV CB INDICATION

19:58:04.609 Rugeley Town 11kV Rugeley Hospital, 11kV CB INDICATION

19:58:22.116 Rugeley Town 11kV Rugeley Hospital, 11kV CB SEQUENCE Triggered.

WPD’s control engineer used a combination of tele-controlled and field-operated manual switching to restore customers’ supplies. Believing that an 11kV fault existed, the circuit was restored in sections, leaving two sections of underground cable de-energised until pressure-tests had been carried-out to ensure their soundness. Both sections were pressure-tested and no fault was found, the underground cables were restored to service (CB tripped /opened when section W restored via the bus-coupler). Fault Log F-19283-E.

The Rugeley Hospital circuit-breaker has since had trip timing tests, a mechanism inspection and relay trip injection testing. All equipment is working correctly and no problems have been found. The protection settings have also been checked and confirmed to be correct.

#### **CB Details**

Protection investigation completed on 11th May 2016 at Rugeley Town 11kV.

Circuit Designation: Rugeley Hospital 11kV

The oil-filled circuit-breaker is a South Wales D6XD 11kV 630A unit.

Last Maintenance Inspection and Operation: 03/05/15

Relay GEC - Overcurrent and Earth Fault (CDG)

On-load trip test carried out following network parallel made.

Test equipment used: PCA2 Relay Engineering.

Overcurrent setting: 8.75 amps with time multiplier of 0.4 sec Earth fault setting 1.5 amps with time multiplier of 0.6 sec

Standard inverse curve - Tested at x2 settings

Overcurrent result: 4053 m/s

Earth fault result: 6017 m/s

CB opening time of 69 m/s

These values all correct for the settings applied.

Note this circuit breaker is 5 physically metres along the 11kV switchboard from the bus-coupler.

*[AE's notes: the AE can confirm the timings quoted are as recorded in WPD's SCADA system. The majority of the detailed information was requested during the audit visit so that the AE could examine whether or not WPD had done all it could to ensure the Rugeley Hospital 11kV circuit-breaker and its associated protection were free from any defects so as to minimise any customer interruptions from incidents affecting other parts of WPD's distribution system in accordance with its licence obligations].*

**Q13. WPD's SoF states that: "The emergency disconnection resulted in the further loss of supplies to 25,117 Customers". Which customers does this statement refer to?**

A13. This statement refers to the loss of all supplies out of Lichfield 132/11kV Primary Substation following the "Emergency disconnection".

**Q14. What protection operated to disconnect the faulted equipment from WPD's distribution system?**

A14. At 19:54:26 at Lichfield the GT1 Buchholz alarm operated. 50 seconds later at 19:55:16 the following occurred in the sequence indicated

- 1) At Lichfield GT1 Main Protection Relay Operated;
- 2) At Lichfield GT1A 11kV OCB Opened;
- 3) At Lichfield GT1B 11kV OCB Opened;
- 4) At Rugeley 132kV Intertrip Received;
- 5) At Rugeley Town 11KV GT1 Intertrip Received;
- 6) At Rugeley 132kV CB 505 Opened;
- 7) At Rugeley Town GT1 11kV OCB Opened.

At 19:55:18 at Lichfield GT1 132kV isolator 113 auto-opened.

Subsequent to this, WPD's SCADA system record that auto-sequence schemes operated at Lichfield and Rugeley Town Primary Substations.

As far as can be determined, these sequence of events are what would have been expected due to a GT1 transformer fault at Lichfield. Obviously something occurred to produce the initial Buchholz alarm with the fault developing for 50 seconds before it was detected by the main protection. There is no reason to suspect faulty protection as this was subsequently tested after the event (with the exception of the Duobias relay which was replaced – however WPD does have Buchholz, HV and LV REF fitted which provide some degree of backup to the Duobias). *[AE's note: the AE confirms that this sequence of operations is as recorded in WPD's SCADA system].*



**Q15. What learning points has WPD incorporated into its procedures as a result of this incident?**

- A15. As indicated at A1 above, WPD has increased its strategic stock holding of 132, 66 & 33kV transformers, LV auxiliary boards, cable sealing ends, etc. Following a review held by Lichfield District Council with respective emergency responders in attendance the following information will be made readily available in any such future incidents:
- The chemical composition of WPD's insulating oil; and
  - A statement on the management of Polychlorinated Biphenyl (PCB's).

**Q16. What further learning points should be considered as a result of the application of the current one-off Exceptional Event Claims process?**

- A16. WPD considers that all exceptional event claims should be subject to timely audit by a person experienced in the Industry.

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

- The most recent tap-changer counter readings for GT1 and GT2 at Lichfield Primary Substation are 111,330 and 113,249 respectively;
- Historic maintenance records for GT1 and GT2 at Lichfield Primary Substation;
- Information to show that the affected section of WPD's network is P2/6 compliant: Lichfield has a recorded maximum demand of 50MVA, and therefore falls into P 2/6 class "C" (over 12MW and up to 60MW). Lichfield has a firm capacity of 60MVA and therefore complies with first circuit outage requirements. (All demand restored by sequence or tele-controlled switching, i.e. within 15 minutes). There is no requirement for a second circuit outage;
- A statement from the site engineers that confirms the request from the fire service to de-energise GT2 at Lichfield Primary Substation to enable the fire service to tackle the fire in safety:

*Fire officer on site with Peter Burgess, WPD's projects team manager and Carl Smith, project engineer. Fire service requested GT2 de-energised in order to tackle the fire on GT1 for safety clearance at 21:20.*

*On arrival at Lichfield Grid 2nd December 2015 Pete Burgess reported to the Staffordshire Fire and Rescue Commander.*

*The situation presented was that of a significant fire on GT1 and a dynamic risk assessment was being undertaken by them at the time with a view to extinguishing the fire.*

*Due to the severity of the fire and the way in which it needed to be extinguished, Carl Smith (Senior Authorised Person) and Pete Burgess were requested to de-energise GT2 for the fire fighters' safety;*

- Sight of WPD's SCADA alarms showing the sequence of circuit-breaker operations during the incident;
- WPD's control room log for this incident: see the control event log as per the copy in WPD's SoF (WPD's INCD-228020-E refers);
- WPD's switching log used to restore supplies as shown in WPD's control switching logs F-19281-E, F-18-Q and F-19283-E;



- WPD's incident reports from which it calculated the CI and CML attributed to this incident as shown control FREP-228083-E, combined SI (FREP-228082-E & FREP-228025-E);
- A representation of the incident on WPD's SCADA system;
- Information regarding WPD's investigations into the spurious tripping of the Rugeley Hospital 11kV Circuit-breaker at Rugeley Town Primary Substation as shown in WPD's responses in A12 above;
- Sight of the third-party report commissioned by WPD of the forensic investigation into the cause of the incident EA Technology. The AE had sight of the investigation report into the failure of the tap-changer fitted to GT1 at WPD's Lichfield Primary Substation. With the extensive damage caused by the fire, WPD's engineers consider the report might only provide an indication of the failure mode and that further investigation may be needed to ensure that a more definitive answer cannot be determined; and
- Information concerning WPD's actions regarding the other tap-changers it has of this type on its distribution system as discussed during the AE's audit visit and as outlined in WPD's responses at A10 above.

## 4. Audit part 2

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

61. In viewing WPD's performance in preventing this incident, the AE has considered what more WPD could have reasonably been expected to have done to ensure that the tap-changer fitted to its number 1 132/11/11kV transformer (GT1) at its Lichfield Primary Substation was well-maintained and free from any known defects.
62. Similarly, the AE has considered what more WPD could have reasonably been expected to have done to ensure its Rugeley Hospital 11kV circuit-breaker and associated protection equipment at its Rugeley Town Primary Substation were well-maintained and free from any known defects.
63. Photograph 1, copied from WPD's SoF, shows the severity of the fire engulfing GT1 at Lichfield Primary Substation on 02 December 2016.
64. Photograph 2, taken the following morning and also copied from WPD's SoF, shows the irreparable damage caused to the same transformer.
65. Photograph 3 is taken from the forensic report commissioned by WPD into the root cause of the incident and shows a close-up view of the damage to the tap selectors.
66. Photograph 4 is also taken from the forensic report and shows the damage to the diverter switches and transition resistors.
67. WPD's measurement systems clearly show the incident unfolding at its Lichfield Primary Substation and the sequence of events concerning the restoration of supplies following the de-energisation of its number 2 132/11/11kV transformer (GT2) in response to the request from the fire service.
68. WPD's measurement systems also clearly show the simultaneous tripping of the Rugeley Hospital 11kV circuit-breaker at its Rugeley Town Primary Substation when the auto-sequence switching closed the 11kV bus-coupler.
69. WPD's measurement systems confirm the restoration of supplies via a combination of tele-controlled and manual switching from the depleted 11kV network following the de-energisation of the number 2 132/11/11kV transformer at its Lichfield Primary Substation, including the deployment of mobile generation.
70. WPD's measurement systems confirm the restoration of its customers supplied via the Rugeley Hospital 11kV circuit-breaker and the subsequent pressure-testing of two underground cable sections to ensure their integrity before being re-energised from the system.
71. An examination of WPD's measurement systems and a SCADA representation of its distribution network confirm that WPD did all it could to restore supplies as expeditiously as possible, particularly as the section of 11kV network was at a depleted state following the loss of both 132kV infeeds to its Lichfield Primary Substation.
72. The AE concludes that, prior to this incident occurring, WPD had done all it could reasonably have been expected to do in considering that its equipment affected by the incident was free from defects and showed no signs of abnormality.

73. The AE also concludes that WPD's distribution system affected by this incident was configured so as to minimise any disruption to customers' supplies in the event of an incident occurring as required by the criteria of Appendix 4 to paragraph 2D.35 of Special Licence Condition CRC 2D.
74. WPD's routine inspection and maintenance policy for the equipment affected by this incident is thorough and was up to date prior to the incident occurring.

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

75. In the AE's experience, damage such as that which occurred to the tap-changer fitted to WPD's number 1 132/11/11kV transformer at WPD's Lichfield Primary Substation is rare and that any abnormality should be detected during routine inspection and maintenance activities.
76. Similarly, the AE's experience indicates that the spurious tripping of 11kV circuit-breakers is also a rare occurrence and can happen from time to time despite the most rigorous inspection and routine maintenance activities, coupled with routine trip-testing.
77. The AE has examined WPD's routine inspection and maintenance procedures and its regime for routine trip-testing of its 11kV circuit-breakers. In all cases the AE has found them fit for purpose and consistent with good practice.
78. Thus, with reference to criteria of Appendix 4 to paragraph 2D.35 of Special Licence Condition CRC 2D, the AE concludes that WPD had done all it could be reasonably expected to do to minimise any interruption to its customers' supplies from this particular incident.
79. The AE has studied the running arrangements of these sections of WPD's network systems and concludes that WPD's protection systems worked correctly to clear the incident affecting the number 1 132/11/11kV transformer at Lichfield Primary Substation from its distribution system.
80. With the exception of the Rugeley Hospital 11kV feeder at Rugeley Town Primary Substation, the AE also concludes that WPD's auto-close sequence switching restored supplies within three minutes following the tripping of the number 1 132kV feeder from Rugeley Grid Substation.
81. Following the above spurious tripping and the de-energisation of the number 2 132kV feeder from Rugeley Grid Substation, the AE also concludes that WPD did all it could to restore its customers' supplies as expeditiously as possible.
82. The AE commends WPD's control engineers for analysing the whole situation, and for their actions in restoring supplies as rapidly as possible, thereby minimising the duration of the interruption to WPD's customers.

#### 4.3 Recommended performance adjustments

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

**Table 3 – Recommended performance adjustments**

	Amount above threshold	Audit part 2 recommendation
CI	0.05	0.05
CML	1.08	1.08



#### 4.4 Detailed justification

84. In reaching a judgement on a recommendation, the AE has firstly considered whether or not WPD could have reasonably taken any different course of action that would have prevented the damage to the tap-changer fitted to its number 1 132/11/11kV transformer at its Lichfield Primary Substation.
85. In viewing WPD'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.
86. The AE notes that WPD has several other transformers fitted with this type of tap-changer and that WPD has no previous records of incidents of this nature affecting this type of tap-changer.
87. The AE also notes that WPD's routine inspection and maintenance procedures are thorough and were up to date at the time of the incident.
88. The AE therefore concludes that WPD had no cause to consider any additional measures other than those consistent with good UK practice.
89. In considering WPD's restoration strategy, the AE is conscious that WPD's duty control engineers acted with commendable skill and speed in analysing the SCADA alarms and indications generated by this incident; and, using a combination of tele-controlled and manual switching, restored supplies as rapidly as possible.
90. Equally, following the fire being extinguished, WPD's actions in restoring the number 2 132/11/11kV transformer at its Lichfield Primary Substation with reduced protection is considered to be a laudable action in WPD's efforts to restore its customers' supplies as quickly as possible.
91. The AE is satisfied that this section of WPD's distribution system complies with the requirements of the security of supply standard P2/6.
92. The Appointed Examiner therefore concludes that WPD's claim is justified and recommends to Ofgem that the amounts of CI and CML above the threshold values should be excluded from WPD West Midlands's performance for reporting year 2015/16.

## Appendix A - Record of Audit part 1

Table A-1: Appointed Examiner's Information Log

"One-Off" Exceptional Event	Reporting Year 2015/16
Licensed Area	WPD(WM)
Date of event	02 December 2015
Cause	Catastrophic failure of a tap-changer fitted to a 132/11/11kV transformer
Notification to Ofgem	07 December 2015
SoF received	14 January 2016
SoF information	<ul style="list-style-type: none"> <li>WPD's distribution system affected by this incident was running normally at the time of the incident;</li> <li>At 19:54 on Wednesday 02 December 2015 the number 1 132kV feeder from Rugeley Grid to Lichfield feed Rugeley Town tripped to clear an incident affecting GT1 at Lichfield;</li> <li>Within 3 minutes, WPD's auto-close sequence switching restored all supplies except the 898 customers fed from the Rugeley Hospital feeder;</li> <li>This feeder was restored section by section with 2 pieces of underground cable being left off until they were pressure-tested okay and restored to service; Extensive investigation by WPD has revealed no problems found with the feeder, the circuit-breaker itself or its associated protection equipment;</li> <li>The fire services requested GT2 be de-energised at Lichfield and all load at Rugeley Town was switched to the number 1 circuit;</li> <li>De-energising GT2 at Lichfield interrupted supplies to 25,117 customers;</li> <li>WPD's 11kV system was depleted (no 132kV infeeds into Lichfield) and customers were restored systematically with load-trimming, LV back-feeding and mobile generation all being used;</li> <li>After the fire was extinguished GT2 at Lichfield was restored with temporary protection and a 25 metre exclusion zone;</li> <li>Back-feeding continued so as to allow GT2 at Lichfield to be de-energised later for restoration of its full protection equipment;</li> <li>WPD has no history of previous problems with this type of tap-changer;</li> <li>No records of problems in the NEDeRS system either;</li> <li>and</li> <li>The following extracts from the post-incident forensic investigation report commissioned by WPD amply demonstrates the irreparable damage to the tap-changer, making a definite analysis of the precise mode of failure impossible: <i>'the damage to the selector cover plate would indicate that an arc developed in this compartment which caused a sufficient force to shear almost half of the studs from the flange face. The selector and diverter</i></li> </ul>



	<p>were physically damaged by the force making a complete evaluation of a mechanical tap-operating fault impossible'.</p> <p>and:</p> <p>'The condition of the OLTC following the fire meant that much of the evidence of where an arc may have developed was lost'.</p>
<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 WPD's responses, is contained in paragraph 59 of the report.
<b>Location of audit visit</b>	WPD's control centre
<b>Date of audit visit</b>	10 May 2016
<b>Visiting Auditor</b>	Geoff Stott (ep)
<b>WPD's Representatives</b>	Pete Burgess, Jim Driscoll, Mick Dunne, Carolyn Hinchey and Richard Skyte
<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 on the findings from the most recent inspection and maintenance reports;</li> <li>• A discussion on the situation regarding this section of WPD's distribution system being P2/6 compliant;</li> <li>• A discussion regarding the learning, the inspection of GT2's tap-changer at Lichfield Primary Substation and the activity to obtain new parts for this showing abnormal wear;</li> <li>• A discussion regarding the restoration of supplies following the de-energisation of GT2 at Lichfield Primary Substation;</li> <li>• The details of what protection operated to clear the incident from WPD's network;</li> <li>• A discussion of WPD's investigations into the spurious tripping of the Rugeley Hospital 11kV circuit-breaker;</li> <li>• A copy of WPD's switching programme for the incident which confirms the timings and events as outlined elsewhere in this report;</li> <li>• Sight of WPD's switching programmes showing the restoration of supplies to WPD's customers affected by the de-energisation of GT2 at Lichfield Primary Substation via a combination of tele-controlled and manual switching, including LV back-feeds and the deployment of mobile generators;</li> <li>• Sight of WPD's switching programme showing the restoration of the customers fed from its 11kV Rugeley Hospital feeder;</li> <li>• Copies of the relevant 132kV to 11kV SLDs;</li> <li>• Sight of the printout from WPD's SCADA system that shows the alarms generated by the event;</li> <li>• A copy of WPD's incident reports that show: <ul style="list-style-type: none"> <li>◦ the total number of customers affected by the</li> </ul> </li> </ul>

	incident to be 26,015; and
	<ul style="list-style-type: none"> <li>the total customer minutes lost due to the incident to be 4,666,532;</li> </ul>
	<ul style="list-style-type: none"> <li>The AE confirms that these figures agree with those quoted in WPD's SoF;</li> </ul>
	<ul style="list-style-type: none"> <li>Using WPD(WM)'s total connected customers at 30 September 2015 of 2,463,217 the number of customers affected equates to a CI of 1.06 <math>[26,015 \times 100 / 2,463,217]</math>;</li> </ul>
	<ul style="list-style-type: none"> <li>Similarly, the customer minutes lost for this event equate to a CML of 1.89 <math>[4,666,532 / 2,463,217]</math>;</li> </ul>
	<ul style="list-style-type: none"> <li>Nothing to be gained from the AE visiting site;</li> </ul>
	<ul style="list-style-type: none"> <li>WPD provided answers to the initial questions plus additional information both during and subsequent to the audit visit; and</li> </ul>
	<ul style="list-style-type: none"> <li>Okay regarding compliance with Appendix 4 of paragraph 2D.35 of CRC 2D.</li> </ul>

**Table A-2: Impact on CI and CML**

	CI		CML	
Voltage (DNO's incident reference)	Claimed	Audited	Claimed	Audited
132kV (INCD-228020-E)	1.06	1.06	1.89	1.89
EHV	0	0	0	0
HV	0	0	0	0
LV	0	0	0	0
Total	1.06	1.06	1.89	1.89
WPD(WM) Threshold (total)	1.01		0.81	
Part 1 Exceptionality Test	pass		pass	
Part 1 Precondition of eligibility (meets App 3 to paragraph 2D.34 of CRC 2D)	pass			

**NOTE:** WPD'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 2015/16.





## Appendix B - Photographs

Photograph 1 – the fire engulfing GT1 at Lichfield Primary Substation



Photograph 2 – the aftermath of the fire





Photograph 3 – the damage to the tap selectors



Photograph 4 – the damage to the diverter switches and transition resistors

