



ofgem

energypeople

**Appointed examiner's audit of One-Off Exceptional Event Claim  
Western Power Distribution (South Wales)  
132kV incident – Swansea North to Ammanford  
07 November 2015**

## Document Properties


Title: Western Power Distribution (South Wales) - Audit of One-Off Exceptional Event Claim - 132kV incident - Swansea North to Ammanford - 07 Nov 2015

Reference: ep/Ofgem/WPD(SWa)/07 Nov '15

Issue: Final report v1.0

Date: 28 October 2016

## Authorisation

Name	Position	Signed	Date
Geoff Stott	Ofgem's Appointed Examiner		28 October 2016

## History

Issue	Date	Originator	Checker	Description
1.0	28 October 2016	Geoff Stott	Glen Chapman	Final version incorporating comments
0.1	07 June 2016	Geoff Stott	Glen Chapman	Draft report sent to Ofgem and to WPD for comment
0.0	31 May 2016	Geoff Stott	-	Pre-draft report created from energypeople template

This document has been prepared for the titled project or named part thereof and should not be relied upon or used for any other project without an independent check being carried out as to its suitability and prior written authority of energypeople. energypeople accepts no responsibility or liability for the consequences of this document being used for a purpose other than the purposes for which it was commissioned. Any person using or relying on the document for such other purpose agrees, and will, by such use or reliance be taken to confirm his agreement, to indemnify energypeople for all loss or damage resulting therefrom. energypeople accepts no responsibility or liability for this document to any party other than the person by whom it was commissioned. Please note that the information or data prepared by parties other than energypeople which has been reviewed in the preparation of this document has not been independently checked or verified for accuracy by energypeople.

## Contents

<b>Glossary .....</b>	<b>4</b>
<b>Summary .....</b>	<b>5</b>
<b>1. Audit part 1 .....</b>	<b>6</b>
1.1 Summary of the main facts .....	6
<b>2. Exceptionality requirements .....</b>	<b>8</b>
2.1 Does the event qualify for exclusion.....	8
2.2 Exceptionality test results .....	8
<b>3. WPD's views of its performance .....</b>	<b>9</b>
3.1 Dealing with the incident .....	9
3.2 WPD's answers to questions on its performance .....	10
<b>4. Audit part 2 .....</b>	<b>18</b>
4.1 WPD's performance in preventing the event .....	18
4.2 WPD's performance in mitigating the effects of the event .....	19
4.3 Recommended performance adjustments .....	19
4.4 Detailed justification.....	20
<b>Appendix A - Record of Audit part 1 .....</b>	<b>21</b>
<b>Appendix B - Photographs.....</b>	<b>24</b>

## Tables

<b>Table 1 – The number of incidents attributed to the event .....</b>	<b>8</b>
<b>Table 2 – Summary of exceptionality test results .....</b>	<b>8</b>
<b>Table 3 – Recommended performance adjustments .....</b>	<b>19</b>

## Figure

<b>Figure 1 – Simplified Network Diagram of WPD's 132/33kV distribution system affected by the incident .....</b>	<b>7</b>
---	----------

## Photographs

<b>Photograph 1 - the metal cap of the glass insulator at the point of failure .....</b>	<b>24</b>
<b>Photograph 2 - the metal pin of the glass insulator at the point of failure.....</b>	<b>24</b>
<b>Photograph 3 - the corrosion within the failed earth wire.....</b>	<b>25</b>
<b>Photograph 4 - a close-up of the corrosion within the earth wire .....</b>	<b>25</b>
<b>Photograph 5 - the failed earth wire lying on the number one 132kV circuit and on the under-running 11kV overhead line .....</b>	<b>26</b>
<b>Photograph 6 – the apex clamp at tower C67 as seen in November 2010.....</b>	<b>26</b>
<b>Photograph 7 - a view of tower C67 showing the disposition of the cross arms.....</b>	<b>27</b>

## 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
ENA	Energy Networks Association
ep	energypeople
NEDeRS®	The UK's National Equipment Defect Reporting Scheme
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(SWa)	Western Power Distribution's South Wales 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 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations at 08:40 on Saturday 07 November 2015 adversely affected the reported performance for its South Wales WPD(SWa) 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 CI but not 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 132kV tower lines is consistent with good practice and was up to date at the time of the incident.
6. The AE also concludes that WPD has surpassed its own conventional inspection regime by employing two specialist organisations to carry-out specific inspection work on its 132kV overhead lines.
7. The AE further concludes that, prior to this incident, WPD had done all it could to ensure its 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations was free from defects.
8. The AE commends WPD's control engineers for restoring customers' supplies as quickly as possible.
9. 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.
10. The AE recommends that an adjustment to WPD(SWa)'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:

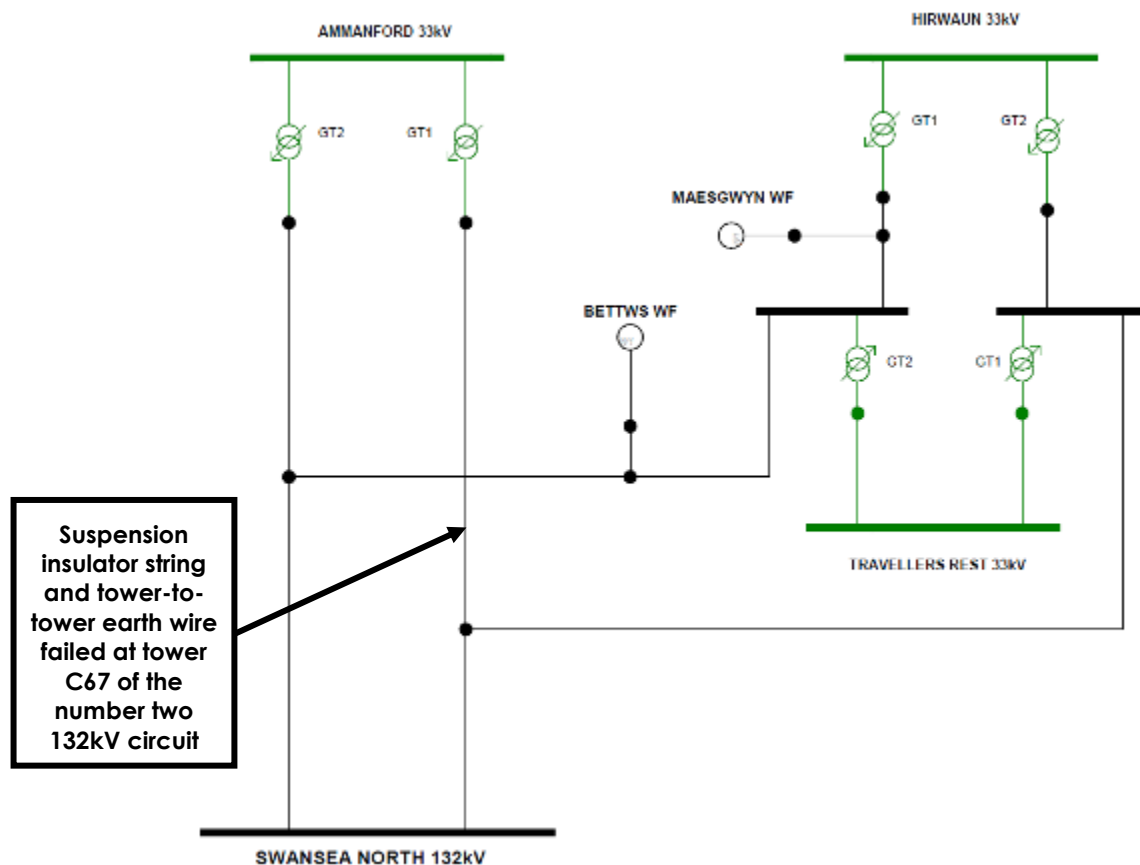
	Audited number	Number above the threshold	Recommended adjustment
CI	6.97	4.71	4.71
CML	0.42	0	0

## 1. Audit part 1

### 1.1 Summary of the main facts

11. 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.
12. WPD's 132/33kV Ammanford Grid Substation is fed via a 132kV double-circuit tower line from its Swansea North Grid Substation.
13. Teed connections from this 132kV double-circuit tower line feed WPD's Hirwaun and Travellers Rest 132/33kV Grid Substations.
14. The outputs from the Bettws and Maesgwyn Wind Farms feed into this section of WPD's 132kV distribution system.
15. WPD has provided evidence to support its claim that the failure of a 132kV suspension insulator string associated with the upper conductor on the number two circuit at tower number C67 of the section of its 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations caused the conductor to fall onto the cross-arm below, thus creating a short-circuit fault to earth.
16. WPD has also provided evidence to show that undetected galvanic corrosion within the inner strands of the over-running tower-to-tower earth wire caused it to fail at the time of the above fault and to fall across the number one 132kV circuit.
17. The resultant tripping of the circuit-breakers controlling both 132kV circuits, resulted in the loss of all incoming supplies to WPD's Ammanford, Hirwaun and Travellers Rest Grid Substations.
18. The failed earth wire also fell across an under-running 11kV overhead line, bringing down two of its three conductors and causing its controlling circuit-breaker to trip.
19. Supplies to 78,311 of WPD's customers were interrupted.
20. WPD commenced the restoration of supplies using tele-controlled switching, restoring 77,685 customers within 20 minutes.
21. A further 540 customers' supplies were restored 30 minutes later via 33kV interconnection.
22. A report from site indicated the cause of the incident and confirmed that both the number one and the number two 132kV circuits, plus the under-running 11kV overhead line could not be re-energised until repairs had been effected.
23. The customers supplied from the damaged 11kV overhead line were restored using mobile generators.
24. WPD removed the failed tower-to-tower earth wire, replacing it with a temporary over-ground arrangement until a permanent re-string was completed during week commencing 09 November 2015. At that time all suspension insulators were also replaced as a precaution against further failure.
25. Taken from WPD's SoF, a simplified view of the section of WPD's 132/33kV distribution system affected by this event is shown in Figure 1.

Figure 1 – Simplified Network Diagram of WPD's 132/33kV distribution system affected by the incident



#### Notes to Figure 1:

1. Only the salient items of equipment are shown.
2. 132kV equipment is depicted in black outline.
3. 33kV equipment is depicted in green outline.
4. WPD's SoF refers to Ystradgynlais Grid Substation – this is represented to the right in figure 1 by the 132kV busbar from which Hirwaun and Travellers Rest 132/33kV Grid Substations are fed.
5. WPD's network was running normally at the time of the incident.

## 2. Exceptionality requirements

### 2.1 Does the event qualify for exclusion?

26. 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.
27. 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

28. 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>

29. 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	2.26	6.97	6.97	pass	4.71
CML exceptionality	1.80	0.42	0.42	fail	0

**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

30. The 132kV busbars at WPD's Ammanford, Hirwaun and Ystradgynlais Grid Substations are fed from the double-circuit tower line emanating from WPD's Swansea North Grid Substation.
31. At the time of the incident the affected part of WPD's 132/33kV system was running normally.
32. When the insulator string failed on the number two circuit and its associated 132kV conductor fell onto the cross-arm below, WPD's protection operated to de-energise the circuit.
33. The virtually simultaneous failure of the tower-to-tower earth wire caused it to fall onto the number one 132kV circuit and the under-running 11kV overhead line.
34. WPD's protection operated to de-energise the number one 132kV circuit and the 11kV under-running overhead line.
35. WPD considers that its protection operated correctly to clear the incidents from its distribution network, the combination of which resulted in the interruption to supplies to 78,311 of WPD's customers.
36. 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.
37. WPD also considers that its control engineers acted correctly in beginning to restore supplies using tele-controlled switching before its personnel reached site and reported back on their findings.
38. Furthermore, WPD commends all those involved in the removal of the failed earth wire and its replacement with a temporary arrangement to allow the early re-energisation of the number one 132kV circuit.
39. WPD also commends its personnel for replacing all the insulators on the affected section of its 132kV tower line and the re-stringing of the tower-to-tower earth wire in the days following the incident.
40. Following the incident, WPD carried-out a detailed examination of the failed insulator string, concluding that the failure was due to undetected corrosion of the pin which engages with the cap of the adjacent insulator.
41. WPD also carried-out a detailed examination of the failed earth wire and found it had failed at a point near to the clamp that secured it to the peak, or apex, at tower C67.
42. The actual cause of the failure was found to be undetected galvanic corrosion between the inner aluminium strands and the central steel core; the passage of the earth fault current being considered the reason it failed during the incident.
43. WPD has replaced all the insulator strings on the affected section of its 132kV double-circuit tower line and found no other instances of the type of corrosion seen at the point of failure on tower C67.
44. Similarly, WPD has replaced the tower-to-tower earth wire along the affected section of its double-circuit 132kV tower line and has found no other instances of galvanic corrosion.

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

45. 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.
46. The AE confirms that WPD's emergency procedures provide for the type of event being examined here.
47. 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.
48. The initial questions were discussed during the AE's visit to WPD's control centre on 17 May 2016, when the records of WPD's SCADA system, the incident report and other information were made available.
49. 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.

**Q2. When was this section of the 132kV dual circuit tower line between Swansea North and Ammanford Grid Substations commissioned?**

A2. WPD's records show that this double-circuit 132kV tower line dates back to CEEB days. WPD we can only estimate that the line would have been commissioned in about 1954.

**Q3. WPD's SoF states that "It is suspected that the suspension set (cap/pin type) had failed due to the internal failure of the cap/pin connection arrangement. Likely failure mode would be internal corrosion."**

**What forensic examination has been carried out to verify this? [AE's note: the AE will need to see the results of these examinations].**

A3. The glass insulator set when lowered was examined and was "rigid" and non-flexible across a number of its connection points where cap meets pin, indicating seated corrosion. Local disassembly confirmed this.

In view of this, WPD considered that no formal forensic examination was needed.

**Q4. What examinations / tests has WPD carried-out on the other suspension sets removed from towers C67/C68?**

A4. All suspension sets in this section (C67/C68) were lowered and inspected soon after the event and replaced with a composite design. (2 sets were replaced on 505 circuit & 2 sets replaced on 205 circuit.)

**Q5. Are all these insulators the original design for the line?**

A5. Yes, WPD believes that this is case.

**Q6. What is the mechanical design rating of these insulators?**

A6. Zebra 190kN & Lynx 125kN.

**Q7. What mechanical loading is imposed on these insulators from the 'long valley span' under maximum wind loading conditions?**

A7. As the line was built by the then CEGB, this information is unknown.

**Q8. What refurbishment / component replacements have been carried out on these circuits since they were commissioned?**

A8. At the locations in question, the fittings were original and work would have been limited to visual inspection only. However, the following work has been completed:

- From C69 to C142 (Ammanford to Ystradgynlais) 300mm + upas-refurbishment circa 1985. (South Wales was under Swalec ownership at this point in time);
- C4 to C21 – all fittings replaced during 2005/06; and
- C21 to C66 – 0.4sqinch Zebra/conductor confirmed good and earth wire confirmed good and externally greased.

**Q9. What design calculations were carried out at the time of any refurbishment?**

A9. As noted above, WPD has no historical data on the original design. However, we are confident in stating that it is heavy construction (0.4 phase conductor/Zebra) with an operating temperature of 50°C/122°F with design for ½" radial ice burden.

**Q10. What specific work has been carried-out on tower C67 since the circuits were commissioned, again with any design calculations if appropriate?**

A10. WPD has not carried-out any work prior to the failure.

**Q11. What is WPD's experience of the reliability of the type of glass insulator string that failed at tower C67?**

A11. WPD has no concerns over the design of this type of insulator. It should be noted that glass insulators have a slightly higher impulse-withstand level than porcelain. However, they are more susceptible to vandalism than porcelain but this tends to be on wood pole lines as a consequence of lower ground clearances. WPD has no records of similar problems at 132kV.

**Q12. What is the UK's reported experience of the reliability of this type of glass insulator string as reported via the ENA's National Equipment Defect Reporting Scheme (NEDeRS®)?**

A12. There are no reported issues in the NEDeRS® database.

**Q13. What is WPD's experience of the reliability of the type of clamping arrangement used to secure the tower earth wire at the apex / peak of tower C67?**

A13. Following the incident, where focus on restoration and network security was priority, it became apparent that initial concerns over the earth-wire apex clamp being defective mechanically were unfounded as the clamp (suspension type) remained in situ.

In fact, the earth-wire failed directly adjacent to the clamp at tower C67 on the tower C66 side and was surprisingly retained on the other side (tower C68). This suggests that the conductor adjacent to the clamp was compromised both mechanically and electrically.

WPD has examined the point of failure of the earth wire and found it to be as a consequence of internal galvanic corrosion.

This was surprising as the external condition was good and there was no relevant information or evidence from foot or helicopter patrols that could reasonably have highlighted this issue.

The internal corrosion would present a high electrical resistance to the flow of earth-fault current at the time of the incident and would have caused the earth wire to fail. **[AE's note: the AE was shown the affected section of the failed earth wire and confirms that internal galvanic corrosion was evident, with no signs being visible on the exterior of the earth wire].**

**Q14. To what known standard is the clamping arrangement designed?**

A14. As per Manual T16/CEGB ref earth-wire fittings: - 68/6493

**Q15. What is the short circuit rating of the clamping arrangement?**

A15. Not applicable – as a suspension clamp it is there to support the earth wire, which in turn provides the 'shield-angle' for the phase conductors against direct lightning strikes.

**Q16. What is the UK's reported experience of the reliability of this type of clamping arrangement as reported via the ENA's National Equipment Defect Reporting Scheme (NEDeRS®)?**

A16. There are no reported concerns: nothing is reported in the NEDeRS® database.

**Q17. WPD's SoF states that "All foot and helicopter bi-annual inspection regimes are up to date and could not foreseeably have identified such a failure associated with the suspension set". What precise operations, including thermographic imaging, are involved in carrying-out the following activities?**

**(a) 'foot inspection regime'?**

A17(a). This is the case and patrols are undertaken on a rolling two-year cycle, alternating between helicopter/foot/helicopter etc. The last foot patrol is dated October 2015. **[AE's note: the AE can confirm that WPD's records show that its foot patrols for this section of its 132kV double-circuit tower line are up to date].**

and

**(b) 'helicopter inspection regime'?**

A17(b). Last helicopter patrol dates:

- Last thermal patrol of the C route was 11<sup>th</sup> April 2014 (this was later than the planned time due to the storms in 2013 and early 2014). The only report from the patrol is for tower 8. No defects recorded or reported for the problem tower (C67).
- Last routine visual patrol of the C route was 02<sup>nd</sup> December 2014.

The following is the data from the C route.

(IS = Shattered Insulator and LF = Land Use - Fishing). These are the only issues found on the C route.

82C68	IS	02/12/2014	13:11:39	M robertson 2
82C69	IS	02/12/2014	13:11:14	M robertson 2
82C73	LF	02/12/2014	13:10:09	M robertson 2
82C74	LF	02/12/2014	13:10:06	M robertson 2
82C77	IS	02/12/2014	13:09:12	M robertson 2



In addition to the above inspection regime, WPD commissioned "Energyline" to carry-out a high definition patrol of the C route in 2010. The only reported thermal defect, highlighted on 11/4/14, was at tower C8 and this has since been rectified.

**[AE's note: the AE can confirm that WPD's records show that its helicopter patrols for this section of its 132kV double-circuit tower line are up to date. They also confirm that WPD commissioned "Energyline's" helicopter patrol during 2014].**

**Q18. What is WPD's policy for the routine testing of the earth resistance of its 132kV towers? [AE's note: this is sometimes known as the 'footing resistance'].**

A18. WPD's policy OH3/6 states that half-cell tests are recommended on tower assets greater than 50 years old. We have not initiated this programme as yet because visual checks on the muff/chimney interface and checking for visible cracking of the foundations, combined with a thorough 3D laser scan to check any tower movement would be initiated before WPD would do any invasive excavations or half-cell checks.

It should be noted that WPD has no concerns over the tower foundations or general steelwork condition of its 132kV double-circuit tower line between Swansea North and Ammanford, teed Ystradgynlais Grid Substations.

Due to the general ageing asset base, WPD has initiated a 10-year hi-resolution imaging "condition evaluation" programme for all steel lattice towers.

"Energyline", a private consultancy within the scientific and engineering community based in Knaresborough, will assist WPD long term with this overhead line condition evaluation.

**Q19. When was this test last carried-out on towers C67 and C66?**

A19. There are no records for these checks as the muff/chimney condition is good and ground conditions stable. Hence WPD has no concerns or requirement to carry-out these tests at this location.

**Q20. What were the results of these tests? [AE's note: the AE will need to see the reports from these tests].**

A20. Not applicable – please see WPD's response at A19 above.

**Q21. WPD's SoF states that, since this incident, "priority has been to replace the suspension sets on C67/68 on both circuits"... In what condition were these insulator strings?**

A21. As stated above, as a precaution, all suspension sets were replaced, as was the earth-wire. The phase conductor and fittings associated with the circuits are in good condition on both circuits.

**Q22. What has WPD done to ensure similar defects are not present in the other insulator strings on the other towers of this 132kV dual-circuit line?**

A22. During the recent circuit outages, climbing inspections were done at other random locations and, as stated previously, both sides of the affected section of the 132kV tower line appeared to be in good serviceable condition.

WPD plans to carry-out further checks to fit-in with outage constraints associated with locally connected distributed generation customers. However, the overall condition of the circuit is good.

**Q23. WPD's SoF suggests that the earth wire probably failed due to "excess / high fault current at the point of failure on tower C67".**

**(a) What calculations and / or tests has WPD carried-out to check the validity of this supposition?**

A23(a). WPD cannot be absolutely certain as no formal calculations have been undertaken and therefore it is correct to deem it a supposition.

However, based on the balance of probability and general condition of the earth-wire (sample provided and seen by the AE during the audit visit), WPD is reasonably confident that the earth wire directly adjacent to the apex clamp was compromised by being in all probability of higher resistance than it should have been. This would certainly have been a factor in its failure when it attempted to pass a proportion of the 8000A of earth-fault current.

and

**(b) What magnitude and duration were used in these calculations / tests?**

A23(b). No formal calculations were undertaken.

**Q24. Against what criteria does WPD's statement imply? [AE's note: for example: excess / high fault current compared with design conditions / new equipment conditions / deteriorated condition / etc].**

A24. It is reasonable to conclude, based on the conductor sample, the point of failure and the value of earth fault current that the failure was as a consequence of poor internal condition of the conductor at the clamp / conductor interface.

It should be noted that this was not externally visible and readily apparent to any visual check. *[AE's note: WPD has provided a high-resolution image of the clamp and apex at tower C67].*

**Q25. What value of earth fault current has WPD calculated for the incident in question at tower C67?**

A25. The actual figures from WPD's Ohmega 406 for the three instances of fault current are as follows:

Fault 1 – 22.895A peak Secondary = 8094A rms Primary.

Fault 2 – 24.662A peak Secondary = 8719A rms Primary.

Fault 3 – 22.462A peak Secondary = 7941A rms Primary.

*[AE's note: WPD has provided a copy of the above figures].*

**Q26. What has WPD done to ensure that a similar earth-wire failure cannot occur in the future? [AE's note: the AE will need to be assured that WPD is doing all that is reasonably practicable to prevent a similar earth-wire failure in the future].**

A26. WPD has engaged "Kinetrics", a company based in Ontario, Canada, to initiate a programme of conductor condition evaluation using its patented "lineVue" technology.

WPD's planned 132kV overhead line refurbishment programme during RIIO-ED1 will target 33 complete tower changes and 81.5km of reconductoring (combined phase / earth-wire total).

**Q27. What protection is fitted to WPD's 132kV dual circuit tower line between its Swansea North to Ammanford feed Ystradgynlais Grid Substations?**

A27. The circuit protection at Swansea North Grid Substation has Ohmega 406 distance protection and full over-current and earth fault back up.

This is combined with triangulated intertripping which was installed and commissioned in 2011.

**Q28. What protection operated to clear this incident from WPD's 132kV distribution system?**

A28. Ohmega distance phase/ground-zone 1

**Q29. What protection is fitted to the 11kV under-running overhead line at WPD's tower C67?**

A29. IDMT overcurrent (setting=300A/0.225TMS);  
IDMT earth fault (setting=90A, 0.225TMS); and  
Sensitive earth fault protection (setting =12A 3 secs DMT).

**Q30. What protection operated to clear the incident from WPD's 11kV overhead line?**

A30. The 11kV circuit was de-energised by the tripping 11kV source ACB 197-252E at Pantyffynon Primary Substation via the IDMT earth fault protection relay.

**Q31. What learning points has WPD incorporated into its procedures as a result of this incident?**

A31. The ageing overhead line asset base for the UK Electricity Supply Industry will require a focus well into RII0-ED2, based upon age profile and general condition monitoring returns. The likely outcome will be greater focus on major overhead line refurbishment over the next 25 years.

**Q32. What further learning points should be considered as a result of the application of the current one-off Exceptional Event Claims process?**

A32. To audit the incident within 3 months of the event occurring so that evidence and information flows are not lost by a change of manager for example.

50. WPD also provided further information both during, and after, the audit visit. This includes:

- Sight of WPD's policy for the routine inspection and maintenance of the type of insulator string that failed.
- The AE also had sight of the reports from the specialist helicopter patrols;
- A discussion regarding WPD's commissioning the specialist Canadian organisation to carry-out corrosion detection work and the dependence of outages on constraints imposed by the various distributed generators connected to WPD's higher voltage distribution systems;
- Examination of the failed earth wire which clearly shows the galvanic corrosion within the inner aluminium strands;
- WPD's 132/33kV Ammanford, Hirwaun and Travellers Rest Grid Substations have a maximum demand of 40.8MVA(40.4MW), 40.2MVA(39MW) and 32.6MVA(31.6MW) respectively. When considered individually, P2/6, requires that the smaller of (Group Demand minus 12MW) and 2/3 of Group Demand be restored within 15 minutes following a first circuit outage. The two 60MVA, 45MVA and 45MVA grid transformers at these locations cater for this requirement. There is no second circuit outage requirement for this category (C) of P2/6.  
The three locations are supplied from Swansea North GSP via 2x132kV circuits and must be considered as a group in the event of 132kV circuit outages: the coincidental maximum demand of the 3 locations is





100.6MVA(99.8MW). Immediate restoration of supply is required in the event of a first circuit outage for this category (D) of P2/6; the 130MVA rating of both 132kV circuits fulfil this requirement. In the event of a second circuit outage there is a requirement, within 3 hours, to restore the smaller of (Group Demand minus 100MW) and 1/3 of Group Demand. For current demand conditions there is no requirement to cater for a second circuit outage but, should demand for the group exceed 100MW, the entire demand of Hirwaun can be transferred to the Upper Boat Grid Group thus satisfying the potential second circuit outage requirement.

- A copy of WPD's SCADA alarms showing the sequence of circuit-breaker operations during the incident;
- A copy of WPD's incident report from which it calculated the CI and CML attributed to this incident; and
- A representation of the incident on WPD's SCADA system.

## 4. Audit part 2

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

51. 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 insulators in the suspension strings fitted to its 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations was inspected and maintained to ensure they were free from any known defects.
52. Similarly, the AE has considered what more WPD could have reasonably been expected to have done to ensure its tower-to-tower earth wire on this 132kV double-circuit tower line was free from any known defects.
53. WPD's examination of the mode of failure of the insulator string concluded that undetected corrosion between the metal parts of adjacent glass insulators within the string had sufficiently weakened the pin so that it pulled out of the metal cap of the insulator immediately below it.
54. Photographs 1 and 2, copied from WPD's SoF show the metal cap and the metal pin respectively of the two insulators at the point of failure.
55. WPD's examination of the failed earth wire have revealed undetected galvanic corrosion between the inner aluminium strands and the central steel support wire at the point of failure at tower C67.
56. Photograph 3, specifically requested by the AE during the audit visit, shows the stripped-back earth wire, revealing the corrosion within the inner aluminium strands. The integrity of the outer aluminium strands is clearly seen in this photograph.
57. Photograph 4, also specifically requested by the AE during the audit visit, shows a close-up of the corrosion affecting the inner aluminium strands of the failed earth wire.
58. Photograph 5, copied from WPD's SoF, shows the fallen earth wire lying across both the number one 132kV circuit the under-running 11kV overhead line.
59. Photograph 6 was also specifically requested by the AE during the audit visit. It is copied from WPD's helicopter patrol database and was taken in November 2010. It shows the apex clamp which supports the tower-to-tower earth wire at tower C67.
60. Photograph 7, again specifically requested by the AE, shows the disposition of the conductors and cross-arms at tower C67. It can be seen that the failure of the insulator string supporting an upper conductor would cause that conductor to fall onto the central cross-arm below.
61. WPD's measurement systems clearly show the tripping of the circuit-breakers controlling the number two 132kV circuit, followed fifteen seconds later by those controlling the number one 132kV circuit.
62. WPD's measurement systems also clearly show the tripping of the 11kV circuit-breaker as a result of the damage of the under-running 11kV overhead line caused by the fallen earth wire.
63. 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.

64. 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.
65. 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.
66. 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.
67. In addition to its routine inspection regime, WPD had also commissioned an organisation that specialises in high-definition helicopter patrols and one that specialises in corrosion detection technology.

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

68. In the AE's experience, the failure of an insulator string such as that which occurred at tower C67 of WPD's 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations is rare and of a type that would lie undetected by inspections until the failure occurred.
69. The AE has examined WPD's routine inspection and maintenance procedures and found them fit for purpose and consistent with good practice.
70. Similarly, the failure of the tower-to-tower earth wire as happened here is rare; the internal corrosion would lie undetected by any conventional ground or helicopter inspections.
71. That said, the commissioning of the additional helicopter patrols and the corrosion detection specialists demonstrates that WPD is doing all it can to ensure the integrity of its equipment.
72. 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.
73. The AE has studied the running arrangements of the affected sections of WPD's network systems and concludes that WPD's protection systems worked correctly to clear the incident from its distribution system.
74. 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

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

**Table 3 – Recommended performance adjustments**

	Amount above threshold	Audit part 2 recommendation
CI	4.71	4.71
CML	0	0

#### 4.4 Detailed justification

76. 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 failure of the insulator string and the tower-to-tower earth wire at tower C67 of its 132kV double-circuit tower line between its Swansea North and Ammanford Grid Substations.
77. 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.
78. The AE notes that WPD has undertaken an investigation into the mode of failure of both the insulator string and the earth wire and has concluded that both would be undetected by any conventional means.
79. 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.
80. The AE also notes WPD's additional helicopter inspections carried-out by a specialist organisation.
81. The AE further notes that WPD has employed another specialist organisation to carry-out corrosion detection work on some of its 132kV overhead lines and intends to extend this to other 132kV lines in the coming months, subject to suitable outages being arranged.
82. The AE therefore concludes that WPD had no cause to consider any further measures other than those consistent with good UK practice and the additional specialist work outlined above.
83. The AE can confirm that the failure modes of the insulator string and the tower-to-tower earth wire would generally lie undetected by conventional visual inspections and hot-spot detection techniques.
84. The AE also confirms that no inspection tests currently deployed would detect the incipient fault within the failed insulator or the earth wire.
85. 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.
86. The AE is satisfied that WPD is pursuing the specialist inspections of its 132kV overhead lines, consistent with outages being arranged with the various distributed generators connected to its higher voltage systems.
87. The AE is satisfied that this section of WPD's distribution system complies with the requirements of the security of supply standard P2/6.
88. The AE therefore concludes that WPD's claim is justified and recommends to Ofgem that the amount of CI above the threshold value should be excluded from WPD South Wales' performance for reporting year 2015/16.
89. That said, any future claims due to this cause will be considered against WPD's progress with the programme of non-destructive testing of its 132kV overhead line conductors and associated tower-to-tower earth wires.

## 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(SWq)
Date of event	07 November 2015
Cause	132kV incident – Swansea North to Ammanford Grid Substations
Notification to Ofgem	09 November 2015
SoF received	20 November 2015
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 08:40 on Saturday 07 November 2015 all supplies were lost from Ammanford, Hirwaun and Travellers Rest 132/33kV Grid Substations;</li> <li>WPD's control engineers began to restore supplies using tele-controlled switching;</li> <li>Personnel sent to site reported a broken insulator string on the number 2 circuit and the associated conductor having fallen onto the cross-arm below;</li> <li>They also reported the broken tower-to-tower earth wire and it having fallen onto the number one circuit and also onto an under-running 11kV overhead line;</li> <li>WPD has no history of previous occurrences of this type of insulator failure;</li> <li>WPD has no history of previous failures of its tower-to-tower earth wires;</li> <li>No records of problems in the NEDeRS system; and</li> <li>As a precaution, WPD has replaced all the suspension insulators and the earth wire in the affected section of its 132kV double-circuit tower line.</li> </ul>
Additional pre-visit information provided	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 49 of the report.
Location of audit visit	WPD's control centre
Date of audit visit	17 May 2016
Visiting Auditor	Geoff Stott (ep)
WPD's Representatives	Lloyd Bridges, Andrew Coates, Huw Evans and Carolyn Hinchey
Information provided during and subsequent to the audit visit	<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 regarding WPD's commissioning "Energyline" to undertake additional inspections by helicopter;</li> <li>A discussion regarding WPD's initiative regarding the commissioning of "Kinetrics" to undertake a programme of evaluating the condition of WPD's overhead line conductors using "Kinetrics" patented technology;</li> </ul>



- A discussion on the situation regarding this section of WPD's distribution system being P2/6 compliant;
- A discussion regarding the examination of the failed insulator;
- A discussion regarding the examination of the failed tower-to-tower earth wire;
- An inspection of the failed earth wire;
- A discussion regarding the restoration of supplies;
- The details of what protection operated to clear the incident from WPD's network;
- A copy of WPD's switching programme showing the restoration of supplies to WPD's customers affected by the incident via a combination of tele-controlled and manual switching, including the deployment of mobile generators to restore supplies to those customers fed from the damaged 11kV overhead line;
- A copy of the printout from WPD's SCADA system that shows the alarms generated by the event;
- A copy of WPD's incident report that shows:
  - the total number of customers affected by the incident to be 78,311; and
  - the total customer minutes lost due to the incident to be 474,141;
- The AE confirms that these figures agree with those quoted in WPD's SoF;
- Using WPD(SWa)'s total connected customers at 30 September 2015 of 1,122,920 the number of customers affected equates to a CI of 6.97  $[78,311 * 100 / 1,122,920]$ ;
- Similarly, the customer minutes lost for this event equate to a CML of 0.42  $[474,141 / 1,122,920]$ ;
- Nothing to be gained from the AE visiting site;
- WPD provided answers to the initial questions plus additional information both during and subsequent to the audit visit; and
- Okay regarding compliance with Appendix 4 of paragraph 2D.35 of CRC 2D.

Table A-2: Impact on CI and CML

	CI		CML	
Voltage (DNO's incident reference)	Claimed	Audited	Claimed	Audited
132kV (INCD-5765-A)	6.97	6.97	0.42	0.42
EHV	0	0	0	0
HV	0	0	0	0
LV	0	0	0	0
Total	6.97	6.97	0.42	0.42
WPD(SW) Threshold (total)	2.26		1.80	
Part 1 Exceptionality Test	pass		fail	
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 metal cap of the glass insulator at the point of failure



Photograph 2 - the metal pin of the glass insulator at the point of failure







Photograph 3 - the corrosion within the failed earth wire



Photograph 4 - a close-up of the corrosion within the earth wire





**Photograph 5 - the failed earth wire lying on the number one 132kV circuit and on the under-running 11kV overhead line**



**Photograph 6 – the apex clamp at tower C67 as seen in November 2010**





Photograph 7 - a view of tower C67 showing the disposition of the cross arms



**AE's note:** from the photograph it is clear that the failure of the suspension insulator on an upper conductor would cause that conductor to fall onto the cross-arm below