Report

Improved Statistical Ratings for Distribution Overhead Lines (Phase 2) Quarterly Report September 2017

Private and confidential

Prepared for: Prepared for WPD

Project No. T7919/SN0004

03 October 2017

Version History

Date	Version	Author(s)	Notes
02/10/17	1	Mark Bertinat	

Final Approval

Approval Type	Date	Version	EA Technology Issue Authority
Final	03/10/17	1	

EA Technology Limited, Capenhurst Technology Park, Capenhurst, Chester, CH1 6ES;
Tel: 0151 339 4181 Fax: 0151 347 2404
http://www.eatechnology.com
Registered in England number 2566313

Summary

This seventh Quarterly Report (QR7) for the Improved Statistical Ratings for Distribution Overhead Lines (Phase 2) project being carried out at the Western Power Distribution (WPD) Stoke site, provides an update of operation since the last Quarterly Report (QR6) published on 1st August 2017 (whilst formally issued as the June 2017 Report, it covered the period March 2017 to end of July 2017).

Contents

1. Project Activity List 3

2. Test-rig Running and Maintenance 4

3. Summary of Progress 5

3.1 Data Checking 5
3.2 Logger and Anemometer Glitches 8
3.3 The CIGRÉ Equations, OHTEMP, and OHTEMP2 8
3.4 Functional forms of OHRAT and OHTEMP 9
3.5 Data Cleansing 9
3.6 Compilation of the Cleansed Dataset 9
3.7 Validation of CIGRÉ Equations - Comparison of Measured and Calculated Conductor Temperatures 11

Appendices

Appendix I **Project Summary Activity Log**

Appendix II **EA Technology Outstanding Task List for Test-rig**

Appendix III **Reactive Maintenance Strategy**

Appendix IV **Maintenance Inspection Check-sheet**

Appendix V **Calendar of Scheduled Project Events**

Appendix VI **Revised Solar Heating Calculation for CIGRÉ Technical Brochure TB601**

1. Project Activity List

The table below illustrates the current status of the activities aligned with Key Deliverables of this project which attempt to ensure continued, uninterrupted operation and timely completion:

Activity / Project Deliverable		Item Description	Status
1	Test-rig Running and Maintenance	Operation and Management Plan	Complete. However, this is a "live" working document so appropriate reviews, amendments and additions are made as the project evolves.
		Decommission Plan	Started but incomplete.
2	Data Entry Checking and Validation	Data Collection and Validation Method Statement	Complete
3	Data Collection and Validation	Data Download Tool	Complete
4	Data Analysis	Data Analysis Method Statement	Complete
		Data Analysis Tool; OHRAT & OHTEMP Functionality	Complete
		Data Analysis Tool; C-T Curve Production Capability	In Progress...
		Data Analysis Tool; Ability to incorporate LDC	Not Started
		Validation of CIGRÉ Methodology	In Progress...
5	Year One	Year One Data Collection Completion	Complete
		Year One Interim Report	Complete as part of QR process
6	Year Two	Year Two Data Collection Completion	In Progress
		Year Two Interim Report	Not Started
		Update ACE104 and ENA ER P27	Not Started
		Decommission Test-rig	Not Started
7	Integrated Software Tool	Specification Developed	In Progress
		"Beta"/Test version of software released	Not Started
		Final Release of Software	Not Started
8	Project Conclusion	Final Project Report Complete	Not Started

2. Test-rig Running and Maintenance

A "live" Test-rig Operation and Management Plan (TOMP) has been developed by the EA Technology project team to ensure the successful operation and optimal evolution of the Overhead Line (OHL) test rig at Western Power Distribution (WPD) Stoke. The current version of the TOMP comprises a list of all items that need consideration aligned with:

- Appropriate OHL rig spares, suppliers and delivery lead times.
- Performance feedback monitoring mechanism.
- External component performance support.
- Scheduled EA Technology review meetings.
- Appropriate level of approval.
- Appropriate resources to perform each task
- Appropriate Risk Assessments & Method Statements (RAMS).

Additional documents were produced during the development of the TOMP, and include:

- Outstanding Task List for the Test-rig.
- Reactive Maintenance Strategy.
- Maintenance Inspection Check-sheet.
- Calendar of Scheduled Events

The **Outstanding Task List for the Test-rig** provides a contemporary record of the ongoing project management status that enables prioritisation and forward planning of tasks. An updated extract of current "live" tasks is demonstrated in Appendix II.

The **Reactive Maintenance Strategy** was formed to minimize down-time and enable efficient response and deployment of resources and is demonstrated in Appendix III.

The **Maintenance Inspection Check-sheet** was composed to ensure that a suite of preventative maintenance activities was performed during site visits to improve rig performance and component service-life longevity and is demonstrated in Appendix IV.

The **Calendar of Scheduled Events** was produced and is coupled with the electronic calendar of the Test-rig Manager, in order to ensure timely planning and execution of significant development or operational activities and is demonstrated in Appendix V.

EA Technology has made a significant number of scheduled and reactive visits to the OHL test-rig site since commencement of data collection to progress task completion and improve rig performance.

Remote monitoring systems, including web-cams, sensory threshold alarms and remote isolation apparatus, have been incorporated into the test-rig control system and continue to assist the EA Technology project team in trying to prevent component failure and mitigate unnecessary down-time.

All activities to date have facilitated improvements in the quality of the OHL test-rig management processes, documentation, and performance.

3. Summary of Progress

The Overhead Line (OHL) conductor test-rig has been formally operational since January 4th 2016, and continues to remain in a predominantly stable condition. The rig is running reliably with automatic daily data download and checking procedures.

3.1 Data Checking

Automated data validation software based on a data-checking-and-visualisation Excel workbook (CHECKDAT) processes the automatic daily data downloads and validates the integrity of the data. CHECKDAT first converts the raw data into engineering units and stores them in a separate worksheet (*condat*). Parameters that show up any malfunctioning of either the datalogger or instrumentation are then evaluated and any variation from set values is notified to members of the project team via email. The daily values of these integrity parameters (which are a mixture of daily totals, daily averages and daily max or min values) are automatically recorded as a row in a monthly output table (one row per day), which features conditional colouring based on how close to a parameter is to its set value. Red indicates the set value has been exceeded. This provides a visual monthly record of the data gathering process. The Output Tables for August and September are shown below (**Table 1** & **Table 2**).

Conductor thermocouples have continued to work effectively since the OHL rig went live in January 2016 and as stated in previous quarterly reports, only one of the 30 conductor thermocouple has given any cause for concern and this was replaced as a precaution. To date, this has been the only issue associated with thermocouple performance.

The validated daily data comprise a minute-by-minute record of the readings of each measurement transducer (thermocouple, current transducer, anemometer etc) converted into engineering units. Each day's data are stored in the "*condat*" worksheet of the relevant CHECKDAT workbook for that day.

.

Table 1: Output Check Table for August 2017

Date	No. of raw dat row s	No. of condat row s	Count A = 4	Count B = 4	TC13, TC14, TC15 max	Tbox max	Tbox min	Thutmax	TPSs max	IC1 = 382	IC2 = 440	IC3 = 443	IC4 = 502	WS1o2	WAA1m2	Rain reset (	Solh1m2	TC1..TC15 TC21..TC3 5 max	TC1..TC15 TC21..TC3 5 min	Trio 11H1 max range	Trio 11H2 max range	Trio 14E max range	Trio 14A max range	Trio 22H1 max range	Trio 22H2 max range	Tamb (line ht)
	raw dat row s	condat row s	countA (w spd avg)	countB (pow er avg)	hottest conductor	Tbox1 & 2 max	Tbox1 & 2 min	Thut1 & 2 max	TPSUs max	IC1 max & min	IC2 max & min	IC3 max & min	IC4 max & min	w s1/w s2	w aa1-w aa2	rain (max mm/min)	abs(solh 1-solh2)	Tcond too high	Tcond too low	Trio 11H1 max range	Trio 11H2 max range	Trio 14E max range	Trio 14A max range	Trio 22H1 max range	Trio 22H2 max range	Tamb for graphs
alarm val	1440	1440	0	0	120	50	0	40	80	1.0%	1.0%	1.0%	1.0%	2	10	1.0	50	150	0	4	4	4	4	4	4	40
														ratio >critval & w s2>1												
Date	R<>crit	R<>crit	R<>crit	R<>crit	R>crit O>crit-10 Y>crit-20	R>=crit O>=crit-5	R<crit, O<cril+1	R>=crit O>=crit-2	R>=crit O>crit-2 Y>crit-5	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval	R>critval O>crit*0.7	R>critval (tip=.254)	R>critval O>crit*0.7 Y>crit*0.3	R>critval	R <critval	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>=crit O>=crit-5 Y>=crit-10
01 August 2017	1440	1440	0	0	63	34	19	27	53	0.6%	0.5%	-0.6%	-0.6%	0	-5	0.00	19	63	24	2.0	1.1	1.2	3.2	2.5	1.3	18
02 August 2017	1440	1440	0	0	55	34	21	26	52	0.6%	0.5%	-0.5%	-0.5%	0	-7	1.02	19	55	18	2.4	2.6	1.3	3.1	3.8	1.8	18
03 August 2017	1440	1440	0	0	50	36	21	28	55	0.7%	0.6%	-0.5%	0.5%	0	-7	0.25	21	50	19	2.0	1.9	1.0	2.7	2.3	2.4	20
04 August 2017	1440	1440	0	0	54	33	21	26	53	0.6%	0.5%	-0.5%	-0.5%	0	-4	0.00	16	54	23	1.9	1.4	1.1	2.9	2.3	1.4	18
05 August 2017	1440	1440	0	0	79	36	19	27	54	0.6%	0.6%	-0.6%	-0.6%	1	0	0.25	19	79	17	2.0	1.2	0.8	1.6	2.3	1.7	20
06 August 2017	1440	1440	0	0	72	34	16	26	52	0.6%	0.5%	-0.6%	-0.6%	8	0	0.25	19	72	18	2.5	2.0	1.2	2.2	2.4	1.8	19
07 August 2017	1440	1440	0	0	74	34	17	26	53	0.6%	0.5%	-0.6%	-0.6%	0	-6	0.25	13	74	20	2.8	2.4	1.3	3.3	2.6	2.4	17
08 August 2017	1440	1440	0	0	81	37	19	28	55	0.7%	0.6%	-0.5%	-0.6%	0	-2	0.25	21	81	23	3.4	2.8	1.3	3.0	3.4	2.1	20
09 August 2017	1440	1440	0	0	73	32	18	24	50	0.5%	0.4%	-0.6%	-0.6%	2	-4	0.25	18	73	17	2.6	1.0	0.9	1.7	2.7	2.1	16
10 August 2017	1440	1440	0	0	81	36	15	27	54	0.7%	0.5%	-0.6%	-0.6%	3	-3	0.25	24	81	19	2.2	0.7	1.1	1.7	2.2	1.7	20
11 August 2017	1440	1440	0	0	81	37	15	29	55	0.8%	0.6%	-0.6%	-0.6%	0	-3	0.00	23	81	24	2.4	1.2	1.0	2.1	2.5	2.3	21
12 August 2017	1440	1440	0	0	56	32	17	24	51	0.5%	0.5%	-0.5%	-0.5%	0	-3	0.25	16	56	24	2.3	2.0	1.3	2.9	2.5	2.4	16
13 August 2017	1440	1440	0	0	79	34	14	27	54	0.7%	0.6%	-0.6%	-0.6%	0	1	0.00	21	79	24	2.4	1.0	0.9	1.7	2.8	2.0	20
14 August 2017	1440	1440	0	0	79	38	16	28	55	0.7%	0.6%	-0.6%	-0.6%	2	-1	0.00	20	79	24	2.3	1.4	1.4	3.1	2.5	2.0	20
15 August 2017	1440	1440	0	0	62	34	19	27	53	0.6%	0.5%	-0.5%	-0.5%	0	-8	0.25	20	62	19	2.0	1.7	1.0	2.0	2.3	2.1	18
16 August 2017	1440	1440	0	0	77	36	16	28	55	0.8%	0.6%	-0.6%	-0.6%	0	2	0.00	19	77	27	2.1	1.3	1.2	2.5	2.5	1.9	20
17 August 2017	1440	1440	0	0	56	35	17	28	54	0.7%	0.5%	-0.5%	-0.5%	0	-8	0.51	17	56	18	1.9	2.6	1.3	2.2	2.8	2.3	19
18 August 2017	1440	1440	0	0	64	38	19	30	57	0.8%	0.7%	-0.5%	-0.5%	5	-3	0.25	27	64	21	4.3	2.9	1.3	3.1	2.7	4.5	21
19 August 2017	1440	1440	0	0	76	34	17	26	54	0.6%	0.6%	-0.6%	-0.5%	3	1	0.25	23	76	17	2.4	1.2	1.1	2.6	2.6	1.8	18
20 August 2017	1440	1440	0	0	56	31	17	24	51	0.4%	0.4%	-0.6%	-0.6%	1	4	0.25	16	56	17	2.5	2.1	1.1	2.1	2.6	2.8	16
21 August 2017	1440	1440	0	0	65	35	19	27	53	0.6%	0.5%	-0.6%	-0.6%	2	0	0.25	17	65	23	2.2	1.7	1.5	3.0	2.5	1.9	18
22 August 2017	1441	1440	0	0	67	32	10	26	53	-82.7%	-99.7%	-84.8%	-100.1%	0	-4	0.23	15	71	-1	71.8	13.3	0.6	16.7	1.9	1.8	17
23 August 2017	1440	1440	0	0	60	37	23	30	57	0.8%	0.7%	0.5%	-0.5%	1	1	0.00	17	60	26	1.9	1.5	0.5	1.3	2.2	2.0	21
24 August 2017	1440	1440	0	0	64	37	18	29	57	0.9%	0.7%	-0.6%	-0.5%	0	-2	0.00	21	64	27	2.7	1.1	1.2	2.7	2.2	1.9	21
25 August 2017	1440	1440	0	0	71	36	19	28	55	0.7%	0.6%	-0.5%	-0.5%	445	1	0.00	17	71	25	1.9	1.1	1.2	2.6	2.4	1.6	19
26 August 2017	1440	1440	0	0	85	37	19	28	55	0.7%	0.6%	-0.6%	-0.6%	162	-2	0.00	18	85	27	2.4	1.6	1.6	3.7	2.8	1.3	20
27 August 2017	1439	1439	2	1	83	241	15	213	57	-94.3%	-100.3%	-100.7%	-94.4%	2	-2	#VALUE!	#VALUE!	195	0	2.9	2.0	6.9	2.9	15.0	112.6	439
28 August 2017	1440	1440	0	0	86	39	16	31	59	1.0%	0.7%	-0.6%	-0.6%	4	-3	0.00	21	86	33	2.3	1.2	1.5	3.4	2.4	1.7	23
29 August 2017	1440	1440	0	0	82	41	20	32	60	1.1%	0.9%	0.7%	0.6%	3	0	0.00	21	82	21	2.1	0.9	1.7	3.4	2.5	1.4	23
30 August 2017	1440	1440	0	0	77	32	18	24	51	0.4%	0.5%	-0.6%	-0.6%	0	-2	0.00	16	77	22	2.2	1.4	1.0	1.8	2.5	1.9	18
31 August 2017	1440	1440	0	0	81	34	13	26	52	0.6%	0.5%	-0.6%	-0.6%	0	-1	0.25	19	81	25	2.4	1.4	0.9	2.2	2.8	1.8	19

Table 2: Output Check Table for September 2017

Date	No. of raw dat row s	No. of condat row s	Count A = 4	Count B = 4	TC13, TC14, TC15 max	Tbox max	Tbox min	Thutmax	TPSsmax	IC1 = 382	IC2 = 440	IC3 = 443	IC4 = 502	WS1o2	WAA1m2	Rain reset (	Solh1m2	TC1..TC15 TC21..TC35 max	Trio 11H1 max range	Trio 11A max range	Trio 11H2 max range	Trio 14E max range	Trio 14A max range	Trio 22H1 max range	Trio 22H2 max range	Tamb (line ht)
	raw dat row s	condat row s	countA (w spd avg)	countB (pow er avg)	hottest conductor	Tbox1 & 2 max	Tbox1 & 2 min	Thut1 & 2 max	TPSUs max	IC1 max & min	IC2 max & min	IC3 max & min	IC4 max & min	w s1/w s2	w aa1-w aa2	rain (max mm/min)	abs(solh 1-solh2)	Tcond too high	Trio 11H1 max range	Trio 11A max range	Trio 11H2 max range	Trio 14E max range	Trio 14A max range	Trio 22H1 max range	Trio 22H2 max range	Tamb for graphs
alarm val	1440	1440	0	0	120	50	0	40	80	1.0%	1.0%	1.0%	1.0%	2	10	1.0	50	150	4	4	4	4	4	4	4	40
														ratio >critval & w s2>1												
Date	R<>crit	R<>crit	R<>crit	R<>crit	R>crit O>crit-10 Y>crit-20	R>=crit O>=crit-5	R<crit, O<cril+1	R>=crit O>=crit-2	R>=crit O>crit-2 Y>crit-5	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval O>crit*0.7	R>critval	R>critval O>crit*0.7	R>critval (tip=.254)	R>critval O>crit*0.7 Y>crit*0.3	R>critval	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>crit O>crit-1 Y>crit-2	R>=crit O>=crit-5 Y>=crit-10
01 September 2017	1440	1440	0	0	75	35	13	26	52	0.6%	0.5%	-0.6%	-0.6%	2	-3	0.25	16	75	2.2	1.5	1.7	1.1	2.5	2.3	2.0	19
02 September 2017	1440	1440	0	0	81	33	13	25	52	0.6%	0.5%	-0.6%	-0.6%	1	-3	0.00	15	81	2.3	1.3	1.1	0.9	1.6	2.3	2.0	19
03 September 2017	1440	1440	0	0	72	37	17	28	54	0.7%	0.6%	-0.6%	-0.6%	0	-4	0.00	28	72	2.1	1.3	1.3	1.3	3.1	2.4	1.8	20
04 September 2017	1440	1440	0	0	47	29	17	22	48	0.3%	0.4%	-0.6%	-0.5%	1	-2	0.25	16	47	1.8	1.3	1.5	0.8	1.3	1.9	2.6	14
05 September 2017	1440	1440	0	0	60	36	21	29	56	0.8%	0.6%	-0.5%	-0.6%	3	-7	0.25	15	60	2.0	1.3	1.9	1.2	3.0	2.2	2.2	21
06 September 2017	1440	1440	0	0	60	34	18	26	53	0.6%	0.5%	-0.6%	-0.6%	0	-2	1.02	13	60	5.6	1.2	4.0	1.8	2.9	4.8	4.8	18
07 September 2017	1440	1440	0	0	61	32	17	24	51	0.4%	0.5%	-0.6%	-0.6%	0	-1	0.00	14	61	1.8	1.2	1.1	1.0	2.6	2.2	1.4	17
08 September 2017	1440	1440	0	0	60	32	17	24	51	0.5%	0.5%	-0.6%	-0.5%	0	-5	0.76	12	60	3.4	1.4	1.7	2.1	3.0	3.4	2.0	16
09 September 2017	1440	1440	0	0	60	33	17	25	52	0.5%	0.5%	-0.6%	-0.6%	1	1	0.25	15	60	2.4	1.2	1.4	1.2	2.6	2.7	1.8	19
10 September 2017	1440	1440	0	0	75	31	16	23	50	0.4%	0.4%	-0.6%	-0.6%	2	-3	0.25	18	75	3.1	1.4	2.1	1.1	2.6	3.2	3.2	17
11 September 2017	1440	1440	0	0	47	30	17	22	49	0.4%	0.4%	-0.6%	-0.6%	1	-5	0.25	13	47	2.0	1.2	1.8	0.9	2.6	2.8	2.1	15
12 September 2017	1440	1440	0	0	41	30	17	23	50	0.4%	0.4%	-0.6%	-0.5%	5	4	0.25	16	41	2.4	1.1	1.4	0.9	2.3	2.6	1.6	16
13 September 2017	1440	1440	0	0	49	31	17	24	51	0.5%	0.5%	-0.6%	-0.5%	0	0	0.25	17	49	1.8	1.1	1.8	1.1	2.9	2.4	2.1	16
14 September 2017	1440	1440	0	0	56	29	15	22	48	-0.3%	0.4%	-0.6%	-0.5%	0	2	0.51	20	56	2.5	1.0	1.8	0.9	2.1	2.8	2.7	17
15 September 2017	1440	1440	0	0	57	30	16	22	49	0.4%	0.4%	-0.6%	-0.5%	4	0	0.25	22	57	2.8	1.0	1.4	0.9	1.4	2.8	1.9	16
16 September 2017	1440	1440	0	0	81	31	14	23	49	-0.3%	0.4%	-0.6%	-0.6%	0	-1	0.25	17	81	2.6	1.3	1.3	0.9	2.1	2.8	1.9	18
17 September 2017	1440	1440	0	0	76	31	12	23	49	0.4%	0.4%	-0.6%	-0.6%	0	-2	0.00	20	76	2.2	1.2	0.9	0.7	1.6	2.4	1.8	18
18 September 2017	1440	1440	0	0	76	32	13	24	50	0.5%	0.5%	-0.6%	-0.6%	0	-3	0.25	24	76	2.1	1.1	1.1	0.8	1.6	2.3	1.8	19
19 September 2017	1440	1440	0	0	73	32	14	23	49	0.4%	0.5%	-0.6%	-0.6%	0	-1	0.25	22	73	7.4	1.4	2.4	1.3	1.8	3.4	2.2	17
20 September 2017	1440	1440	0	0	82	33	14	24	51	0.5%	0.5%	-0.6%	-0.5%	0	-3	0.00	25	82	2.4	1.5	1.1	1.2	2.9	2.4	1.9	20
21 September 2017	1440	1440	0	0	48	33	18	25	52	0.5%	0.5%	-0.5%	-0.5%	0	-8	0.00	13	48	1.7	1.0	1.3	0.9	2.5	2.1	1.4	17
22 September 2017	1440	1440	0	0	75	29	11	22	48	-0.3%	0.4%	-0.6%	-0.6%	1	-3	0.25	15	75	2.5	1.2	1.6	0.9	1.6	2.7	2.4	15
23 September 2017	1440	1440	0	0	71	30	11	23	49	0.4%	0.4%	-0.6%	-0.5%	0	-7	0.00	22	71	2.3	1.1	1.3	0.9	2.3	2.1	2.0	15
24 September 2017	1440	1440	0	0	52	31	18	24	51	0.6%	0.5%	-0.6%	-0.5%	0	-5	0.00	14	52	1.8	1.0	1.0	0.6	1.3	1.8	1.5	17
25 September 2017	1440	1440	0	0	70	34	18	26	54	0.6%	0.5%	-0.6%	-0.5%	0	0	0.25	11	70	1.8	1.2	1.5	0.9	2.2	2.1	2.2	19
26 September 2017	1440	1440	0	0	83	33	18	25	52	0.5%	0.5%	-0.5%	-0.6%	0	2	0.00	12	83	2.1	1.4	1.3	0.8	1.6	2.5	2.2	16
27 September 2017	1440	1440	0	0	53	33	20	24	51	-99.7%	-99.8%	-99.8%	-99.8%	0	0	0.51	11	53	1.8	1.0	0.7	0.8	1.0	1.8	1.7	18
28 September 2017	1440	1440	0	0	70	32	20	25	52	0.4%	0.5%	-0.5%	-0.5%	8	1	0.25	12	70	2.5	0.9	1.9	0.9	1.7	2.3	2.9	16
29 September 2017	1440	1440	0	0	73	35	20	26	53	0.6%	0.5%	-0.5%	-0.5%	2	2	0.00	25	73	2.4	1.4	1.4	1.5	3.5	2.6	1.9	18
30 September 2017	1440	1440	0	0	60	33	15	25	51	0.4%	0.5%	-0.6%	-0.5%	0	1	0.25	16	60	2.5	1.3	2.0	1.2	3.2	2.5	2.4	17

3.2 Logger and Anemometer Glitches

Logger Glitches

The unexplained logger glitches reported in the June Quarterly Report (QR6) seem to have been largely cured by a minor modification to the logger (replacement of battery back-up link) on 9th June 2017. Logger glitches have been dealt with by deleting the suspect row in *condat*, plus one row either side of it.

In August, only 2 days suffered any logger glitches (3 on 22nd and 1 on 27th) resulting in the loss of 27 rows of data (out of a total of 44640). There have been no logger glitches in September.

WindMaster Anemometer Glitches

The unexplained 3D WindMaster anemometer glitches reported in QR6 have also become much less frequent although the reason for this is not apparent. These glitches are generally short-lived but occasionally they last for last several hours. Fortunately, as stated in the QR6, the 2D WindSonic anemometer is generally operating reliably, so during a WindMaster glitch, only the data relating to the WindMaster anemometer have been deleted leaving an otherwise valid row of data including on the readings of the 2D WindSonic anemometer. Since we generally take the average of the two anemometers as usual (see

Table 3) then simply gives us the WindSonic reading.

In August 2017, there were 12 days affected by WindMaster glitches with 718 rows of data affected. Of these, 642 occurred in two major events on the 25th and 26th August. In September, 8 days suffered glitches with only 42 rows of data affected.

Replacing the anemometer with a similar instrument (1st July 2017) has not completely solved the WindMaster glitch problem so we have recently (26th September 2017) replaced the cable connection between anemometer and data logger in an effort to eliminate the remaining glitches. Unfortunately this too has not solved the problem – there were 6 and 2 glitches respectively on the following two days (followed by two days with no glitches).

3.3 The CIGRÉ Equations, OHTEMP, and OHTEMP2

CIGRÉ Technical Brochure TB601, "Guide for thermal rating calculations of overhead lines" (2014) contains a set of equations for calculating the temperature of overhead conductors under specified conditions. It is an update of the equations previously compiled by CIGRÉ WG22.12 and published in Electra in 1992.

OHTEMP is a spreadsheet tool developed in 2010 by EA Technology for members of the Overhead Line Module of the STP that uses the 1992 CIGRÉ equations to calculate the temperature of a conductor carrying a specified current under specified ambient conditions. A revised version, **OHTEMP2**, that incorporates the new (2014) CIGRÉ equations has been developed as part of the present project.

OHTEMP3 is a fixed-data version of OHTEMP2 (one for each conductor-current combination in this project) used in initial comparisons of experimental and calculated data.

It was noted in QR6 that the solar gain equations given in TB601 are incorrect. A revised set of solar gain equations developed by MPB are to be published in a revised version of TB601. The revised solar gain equations are used in OHTEMP2: they can be found in Appendix VI.

3.4 Functional forms of OHRAT and OHTEMP

Functional forms of both OHRAT and OHTEMP2 (**OHRATf** and **OHTEMP2f**) have been developed using the 2014 CIGRE equations. All the equations are written in VBA software code rather than formulae in an Excel spreadsheet. These will be used in ongoing data analysis and are easily transferable to alternative languages for use in the eventual software tool.

The Rating Function (OHRATf) takes three inputs – an input temperature, a conductor type and the season. The seasons used are currently the existing P27 seasons but can be easily altered to fit any findings at a later stage of the data analysis. The conductor properties currently included are only the conductors used in this project. However, additional conductor types can be included for use in the final software tool as and when required. The temperature input is the design temperature. The function includes constants specific to the Stoke rig site such as altitude and latitude but these can be altered to accommodate different locations.

The Rating Function currently produces the deterministic rating or "design current", i.e. the current corresponding to the specified design conditions. This can be changed as and when required to include a desired/acceptable exceedance level as a fourth input to the function.

The Temperature Function (OHTEMP2f) also takes three inputs – the conductor type, the season and the current. Again, the seasons currently used are P27 seasons and the conductor types are solely the ones used in this project. However, both sets of properties can be amended/extended at latter stages of the project as and when required.

Both functions use an iterative process (a maximum of 15 iterations) to determine the correct rating or temperature.

3.5 Data Cleansing

Effort is currently being concentrated on ensuring the "cleanliness" of the final dataset.

The **Cleansed Dataset** will essentially comprise a concatenation of all the daily *condat* data, initially into monthly blocks but then, if required, into seasonal and/or annual blocks. However, before they are concatenated, the daily *condat* files need to be further checked and, if necessary, cleansed.

There have been two main sources of corrupt data: (a) logger glitches, where lines of data are either missing, or duplicated, or contain obvious errors; and (b) anemometer glitches, where the readings from the 3D WindMaster anemometer are either impossibly high or are suddenly very different from previous readings (and those of the 2D WindSonic anemometer) – see Section 3.2.

An automated cleansing routine has been incorporated into the CHECKDAT process to try and deal with these glitches. This deletes part or all of any suspect row in the *condat* sheet plus one row either side of it. For logger glitches, complete rows of data are deleted but for the anemometer glitches, only the data relating to the suspect anemometer have been deleted.

Unfortunately, features of the EA Technology computer network, and the way that the Windows system updates, mean that an automatic data cleansing routine cannot be completely reliable. Moreover, with so many sensors, new situations continue to arise which are not dealt with by the automatic cleaner. For both of these reasons, there is still a need for daily manual checking of the data.

3.6 Compilation of the Cleansed Dataset

The **Cleansed Dataset** will essentially comprise a concatenation of all the daily *condat* data, initially in monthly blocks but then, if required, in seasonal and/or annual blocks.

After cleansing, the data need a certain amount of data processing since many of the measuring instruments are duplicated or triplicated in order to provide redundancy in the event of a malfunction. For these parameters, a suitable "best" value, needs to be defined. This is usually the mean of the two or three readings.

The only possible exceptions are the conductor thermocouple trios. In previous work it was found that a low conductor thermocouple reading was often an indication of poor thermal contact between the thermocouple and the conductor and so the maximum of the trio was deemed the most appropriate choice. In the present work, this is less-obviously the case. In fact, as we have seen, the trio means may give better agreement with the calculated values than the trio maxima. The draft dataset will include both trio means and trio maxima. It will be a simple matter to remove the unwanted ones in the final version.

The parameters for which a suitable "best" value needs to be determined are shown in **Table 3**.

Table 3: Parameters for which a suitable "best" value needs to be determined

				complication
Tcon	conductor temperatures	trios of thermocouples	mean or max	max = best contact?
Tamb	ambient temperature (line height)	pair of thermocouples	mean	
Wspd	wind speed (line height)	pair of anemometers	mean	different outputs
Waa	wind attack angle	pair of anemometers	mean	different outputs
Sol	solar insolation	pair of solarimeters	mean	shadows

The cleansed and concatenated data files for January to December 2016 were delivered to Sven Hoffmann by email on 1st June 2016. It was pointed out in the email text that the rainfall column, which should show the aggregate mm/h, in fact contained the 1-min readings but we decided not to delay sending the data on account of this.

It had also proved necessary to correct all the 2016 concatenated data following an improvement in the way the Hazel currents were derived from the raw data (see QR6 Section 3.3.4). Unfortunately, expediency meant that the corrections were carried out in two different parts of the program according to whether we were dealing with pre-fire or post-fire data. Although the calculations were the same in the two cases, the importance of consistency has led to the decision to rerun the concatenation of the 2016 files. The opportunity will be taken to also correct the rainfall column to show the aggregate mm/h, as discussed above.

3.7 Validation of CIGRÉ Equations - Comparison of Measured and Calculated Conductor Temperatures

An initial comparison of measured and calculated conductor temperatures was carried out for a single day (29/9/16) and reported in QR6. The calculated temperatures were obtained using OHTEMP3, the fixed-data version of OHTEMP2 (see Section 3.3).

The measured and calculated temperatures for each of the 10 conductor-current combinations conductor were compared every minute of the day and the average difference determined.

Comparisons were carried out using both the trio means (the mean of the readings of the three thermocouples mounted on each conductor) and the trio maxima (the maximum of the three readings) as the measured values. Trio means were found to give rather better agreement than trio maxima.

It was also found that better overall agreement was obtained if a 10-minute running mean was used for the calculated values.

For trio means and 10-minute running means, daily averages generally agreed to within about 2°C for all conductors. For the hottest conductor, 14A (i.e. Ash 500), the average differences were 0.73 (±2.0)°C (the ± figure is the standard deviation). The overall average across all conductors was 1.05°C.

This has now been repeated using the functional form of OHTEMP2f (see Section 3.4) for the day in each month in 2016 when the conductor temperatures were highest. Table 4 and Table 5 show the summary results for the differences obtained with trio means and trio maxima respectively. The overall means of 1.77°C for the former and 2.24°C for the latter confirm the earlier finding that the trio means show better agreement with the calculated values than do the trio maxima.

A more detailed comparison is in progress to determine how the difference varies with wind speed and/or conductor temperature and conductor size.

Table 4 Measured (trio means) vs calculated conductor temperatures – 2016 hot days

Trio means minus calculated values with 10-min running mean **Average differences over a hot day**												
2016	20-Jan	27-Feb	13-Mar	14-Apr	27-May	03-Jun	21-Sep	30-Oct	16-Nov	19-Dec	mean	st dev
11H1	2.52	0.05	-0.36	-1.69	0.32	-2.85	1.91	1.32	0.42	2.62	0.43	1.77
11A	4.60	1.51	2.55	0.10	2.93	-0.31	1.50	1.38	-0.05	2.04	1.62	1.51
11H2	6.88	3.44	5.59	3.25	6.14	2.76	2.20	2.07	1.01	3.22	3.66	1.92
14E	5.09	1.84	2.12	-0.02	3.11	-0.86	1.37	0.04	-0.94	1.47	1.32	1.87
14A	7.02	1.18	3.26	-0.01	3.64	-1.10	1.39	0.72	-0.81	2.53	1.78	2.44
22H1	3.49	1.10	1.49	-0.11	2.95	-1.03	2.19	1.50	0.24	2.46	1.43	1.42
22A	5.50	1.41	2.68	-0.03	3.35	-0.45	1.37	0.68	-0.44	1.69	1.58	1.87
22H2	7.78	2.78	3.93	1.67	4.82	0.65	2.35	1.89	0.57	2.97	2.94	2.16
23E	5.28	1.92	3.10	0.73	3.98	0.73	2.33	1.52	0.55	3.09	2.32	1.55
23A	4.40	0.64	1.72	-0.93	2.47	-1.29	0.52	-0.55	-1.42	1.07	0.66	1.85
mean	5.26	1.59	2.61	0.30	3.37	-0.38	1.71	1.06	-0.09	2.31	1.77	1.72
st dev	1.63	0.98	1.58	1.37	1.52	1.50	0.59	0.83	0.79	0.73	0.98	

Table 5: Measured (trio maxima) vs calculated conductor temperatures – 2016 hot days

Trio maxima minus calculated values with 10-min running mean **Average differences over a hot day**												
2016	20-Jan	27-Feb	13-Mar	14-Apr	27-May	03-Jun	21-Sep	30-Oct	16-Nov	19-Dec	mean	st dev
11H1	3.38	0.83	0.31	-1.01	0.96	-2.19	2.57	2.00	1.05	3.34	1.12	1.80
11A	5.08	1.94	2.99	0.54	3.40	0.09	1.93	1.76	0.32	2.52	2.06	1.54
11H2	7.30	3.67	5.85	3.46	6.35	2.94	2.39	2.36	1.31	3.66	3.93	1.94
14E	5.45	2.18	2.50	0.24	3.34	-0.60	1.62	0.40	-0.62	1.73	1.62	1.89
14A	7.86	1.65	3.92	0.40	4.05	-0.42	1.78	1.32	-0.24	2.99	2.33	2.50
22H1	4.22	1.74	2.19	0.63	3.59	-0.31	2.86	2.20	0.92	3.17	2.12	1.41
22A	5.81	1.66	3.05	0.23	3.62	-0.17	1.64	1.19	0.00	2.08	1.91	1.85
22H2	8.11	3.19	4.24	1.99	5.24	1.13	2.75	2.23	0.88	3.30	3.31	2.15
23E	5.79	2.42	3.58	1.20	4.46	1.15	2.79	1.95	1.03	3.66	2.80	1.58
23A	4.96	1.42	2.26	-0.40	2.97	-0.87	1.03	-0.10	-0.90	1.64	1.20	1.87
mean	5.80	2.07	3.09	0.73	3.80	0.08	2.13	1.53	0.37	2.81	2.24	1.74
st dev	1.55	0.84	1.47	1.26	1.42	1.39	0.62	0.83	0.78	0.77	0.89	

Appendix I Project Summary Activity Log

A summary of the most significant issues attended to since the previous quarterly report:

Date	Issue Description	Date Resolved	Action and Consequence
2017-08-05c	1 WMaster Glitch (3 rows).	07/08/2017	Deleted faulty WMaster data
2017-08-06c	1 WMaster Glitch (24 rows).	07/08/2017	Deleted faulty WMaster data
2017-08-08c	1 WMaster Glitch (3 rows)	08/08/2017	Deleted faulty WMaster data
2017-08-10c	1 WMaster Glitch (3 rows).	10/08/2017	Deleted faulty WMaster data
2017-08-13c	2 WMaster Glitches (6 rows).	13/08/2017	Deleted faulty WMaster data
2017-08-14c	1 WMaster Glitch (3 rows).	14/08/2017	Deleted faulty WMaster data
2017-08-18c	4 WMaster Glitches (15 rows).	18/08/2017	Deleted faulty WMaster data
2017-08-21c	2 WMaster Glitches (6 rows).	21/08/2017	Deleted faulty WMaster data
2017-08-22cr	Logger glitch: 0508/9 duplicated, 0509 & 0513 corrupt, 0514 missing.	21/09/2017	Deleted faulty data, inserted missing times
2017-08-25c	13 WMaster Glitches (468 rows).	25/08/2017	Deleted faulty WMaster data
2017-08-26c	13 WMaster Glitches (174 rows).	26/08/2017	Deleted faulty WMaster data
2017-08-27r	Logger Glitches 0621-0629, 1307-1313. WMaster glitch 2042-2047.	04/09/2017	Deleted faulty data, inserted missing times. Deleted faulty WMaster data.
2017-08-28cr	4 WMaster Glitches (12 rows).	04/09/2017	Deleted faulty WMaster data
2017-08-28cr	Solarimeters disagreed for about 90 mins around 1200		
2017-08-29r	1 WMaster Glitch (1 row)		Deleted faulty WMaster data
2017-09-01c	2 WMaster Glitches (6 rows)	05/09/2017	Deleted faulty WMaster data
2017-09-04c	1 WMaster Glitches (3 rows)	05/09/2017	Deleted faulty WMaster data
2017-09-05c	1 WMaster Glitches (3 rows)	05/09/2017	Deleted faulty WMaster data
2017-09-06cr	Spikes in Hazel trio ranges possibly due to heavy rain followed by sunshine:	07/09/2017	Deleted Hazel data in trios: 11H1 1100-1120, rest 1100-1110
2017-09-10c	1 WMaster Glitches (3 rows)	10/09/2017	Deleted faulty WMaster data

Date	Issue Description	Date Resolved	Action and Consequence
2017-09-12r	autocheckdat crashed without producing corrected version 2017-09-12c (OK with 09-11 and 09-13)	12/09/2017	
2017-09-15c	3 WMaster Glitches (12 rows)	15/09/2017	Deleted faulty WMaster data
2017-09-18c	1 WMaster Glitches (3 rows)	18/09/2017	Deleted faulty WMaster data
2017-09-22c	2 WMaster Glitches (6 rows)	22/09/2017	Deleted faulty WMaster data
2017-09-22cn	Wmaster glitches 0745 and 1946	22/09/2017	Deleted faulty WMaster data
2017-09-22cn	Wmaster glitches 0745 and 1946	22/09/2017	Deleted faulty WMaster data
2017-09-27cr	Replaced WMaster anemometer cable in attempt to stop glitches	27/09/2017	Data deleted in raw data csv from 9:00 to 12:00 (180 rows).
2017-09-28cr	6 WMaster Glitches (18 rows) - new cable not stopped glitches. Also several identical WMaster readings either side of auto-removed glitches (30 rows).	28/09/2017	Deleted faulty WMaster data incl. runs of identical WMaster readings. 48 rows total.
2017-09-29c	2 WMaster Glitches (6 rows)	29/09/2017	Deleted faulty WMaster data

Appendix II EA Technology Outstanding Task List for Test-rig

Task List A	Outstanding Tasks at / for Test-site, Stoke Last updated: 16/05/17			Index page Contact List
Priority	Person Responsible	Problem/Action/Event/Comment	Comment or Est'd time (hrs)	Phase (1 or 2)
	JDC/MPB/RA (AW)	Integrate 'High Temperature Warning" notification into Datataker system to act as a pre-cursor alert to 'Over-temp Tripping Event'. Identification of TC that will be used to trigger warning is still TBC.	(18/05/16) Determined by JDC & MPB that: Datalogger Warning @ 38ºC [MPB] & Trip @ 42ºC [RA]; Squirrel Trip at 43ºC [AW]	Pre-visit tasks Tasks at Stoke To take
	PT/NJH	Replace U/S 'curtain-fan' fans: approx. 4 have failed. SUNON, EEC0252B2-000U-A99, DC24V, 3.5W T:\NIA Folders\NIA Projects\Projects\SN0004\SN0004 - Site Visits\Phase 2\photos\2017_04_06 maintenance & check wiring for split currents\IMG_0402		
	RA	Identify/source UPS for PC & Modem and plan installation	Ongoing **[1h]** PT discuss w/ RA	
	NJH	PAT test equipment onsite	NJH to perform 16/01/17 **[1h]**	
	All	Monitoring of site Web-Cams during staff visits		

Task List A	Outstanding Tasks at / for Test-site, Stoke	Last updated: 16/05/17		Index page Contact List
	TBC	1. Adjust PSU auto control current settings after calibration factors have been properly determined by JDC and MPB. 2. Complete new Maintenance Inspection Check-sheet 3. Disco' wall heater if AJ Electrics didn't do during their recent test.	Most recent Maint. Check Sheet completed and wall heater used whilst onsite; It performed ok; on 07/11/16 by NJH.	
	NH/MPB/RW/RA	With assistance from WPD MEWP, investigate anemometer anomalies. RW: Liaise w/ WPD for MEWP access. Activity to be performed during next visit.	NJH/RA/MPB to visit site on 16/01/17 to investigate. **[1.5h for 2 people]**	
	RA	Set up email (~~text~~) alert for 'Rig-tripped' alarm; recipients to be PT & RW (plus RA & MPB if they so desire)		
	Team	Consider implication(s) of dry grass-cuttings entering cabin through vent holes in floor.	No issues arose during remainder of 2016. Reassess during 2017 summer period.	
	JDC/MPB	Ongoing review of Datataker & Squirrel over-current/over-temp thresholds Current settings (04/08/16): • Datataker: PSUs set at 80ºC; THUTs set at 40ºC. • Squirrel: PSU 1-3 currents set at >10%; PSU 4 >5%; THUTs 43ºC		
	Team	Review performance feedback loop (Frequency of meetings, sensor threshold alarms, trigger recipients, webcam review, etc.)		

Task List A	Outstanding Tasks at / for Test-site, Stoke	Last updated: 16/05/17		Index page Contact List
	MPB	Monitor ambient temperature within auxiliary pole cabinets. Consider installation of localised heating if ambient temp. =<0ºC. Specification for Digirail Modules TBC by OMNI	Reminder sent to MPB to be alert of ambient temps/performance (11/01/17)	
	JDC/MPB	Confirm how close the PSUs are running to their limits during warmer seasons (MPB to liaise w/ JDC)		
	PT	Ongoing periodic review of Safety Documentation.		
	PT	Identify & source spares required for Stoke. Review team spares list. PT set up workable document in job folder: all team to add to list appropriately.	Ongoing consideration	
	RW/PT	1page PR document for WPD (A. Pickering to approve all pics)		
	PT/RW	Closing project review for EATL/WPD/Suppliers/DNOs/Project members		

Appendix III Reactive Maintenance Strategy

Reactive Maintenance Strategy				Last updated:					8/01/2016
Class of emergency				Actions available		Resources available			
	Emergency	Questionable	Non-emergency			Resource		Contact Details (7am-10pm)	
1	Threat to safety and health of people	Vandalism?	Power outage	A	Do nothing except record details of communication	1	EATL	Project Manager	Richard Wood	0151 347 2387 07854 401802
2	Threat to rig safety and/or functionality	Foreign objects within compound…		B	Remotely interrogate webcams	2		Test-rig Manager	Peter Thompson	0151 347 2402 077183 40551
		…close to or touching test-rig components	…remote from test-rig components							
3	Threat to WPD operations	OHL conductor falling/fallen down	Other?	C	Confirm receipt of 'Rig-tripped' text alert	3		Data Manager	Ramiz Ahmed	0151 347 2333 07891 236893
4	Trespassers within compound	OHL pole crossarm falling/ fallen down		D	Contact WPD reception, security or Electricity Supplier	4		Electrical Engineering Guidance	John Crabtree	0151 347 2337 (O) 07841 492595 (W) 07704 572786 (P) 01244 328961 (H)

5		Fencing/gate failure		E	Liaise with resource informatively	5	Test-rig design (Primary contact)	Mark Bertinat	0151 347 2391 07817 909797
				F	Contact emergency services informatively at an appropriate point in time	6	Test-rig design (Secondary contact- ONLY during normal working hours)	Alan Ward	0151 347 2349 (ONLY during normal working hours)
				G	Isolate power to rig remotely	7	OHL Design	Richard Wood	0151 347 2387 07854 401802
Note: We currently foresee that the only cause for immediate attendance to the Test-site outside of normal working hours would be if the Emergency Services and/or WPD were to insist that we do so.				H	Contact emergency services immediately	8	Health & Safety Advisor	Greg Watson	0151 347 2256
				I	Liaise with and deploy resource at an appropriate time	9	Technical Engineers	Ralph Eyre-Walker	0151 347 2375 07894 392833

J	Liaise with and deploy resource immediately

10	WPD	Test-rig design	Sven Hoffmann	
11		OHL Team	Shane Degg	07989 700472
12		Network Connection Team		
13		Stoke Depot Security	Nigel Morris	01782 403706
14	Electrical Contractor	AJ Electrics (Local to Test-site)	Chris Huxley	01782 205814 07718 027814
15	Data loggers	OMNI (0845 9000 601)	Andy Philpott	07595 120791
16			Steve Duncan	07908 753933
17	PSUs	REO	Steve Hughes	01588 673411
18	ITs	Birmingham Transformers	Mark Waidson	0121 764 5600
19	Npower	Commercial Premises Supplies	Ed Davies	0800 912 7723
20	Grounds Maintenance	Hortech Grounds Maintenance	John Shufflebotham	01782 416653 07866 704854

21			Peter Tilley	01782 416653 07896 832637
22	Porta-cabin	Concept Cabins	Darren Trinder	07733 763864

Appendix IV Maintenance Inspection Check-sheet

Task List D	Maintenance Inspection Check-sheet	Version update: 26/01/16	Maintenance Inspection completion date:

Description:

The Maintenance Inspection Check-sheet is a guide for the routine maintenance tasks associated with the OHL Test-rig.
A new document should be printed prior to visiting site and completed during each inspection.
The completed documents should be returned to the Test-rig Manager and stored at EA Technology's head-office, Capenhurst.

Module		Component		Action	Frequency	HR	Equipment required	Initials	Comments
	Test-rig control & monitoring equipment (Indoor)	A	Weld cables	Visual assessment[1] and comparative sweep across the four supplies w/ FLIR	Each visit[2]	TE	FLIR/iPhone FLIR		
				Torque check of terminated lugs (44Nm) and bolted terminations	During quarterly scheduled inspection ONLY when Test-rig is isolated	TE	Calibrated torque wrench, adaptors. Work Instruction including specified torque		

[1] 'Visual assessment' refers to the observational process of assessing the mechanical condition of each component associated with the stated item, where practicable and safe to do so, by employing an appropriate level of manual handling, tooling, interference and/or component movement in order to assess the actual condition of component materials, assemblies, fixings, and/or wirings without causing unnecessary or irreversible disturbance that could render the components vulnerable to failure or dysfunctional operation. All noteworthy observations, reparatory works, pro-active maintenance actions or considerations must be recorded and communicated to the appropriate responsible person in a timely manner for means of traceability and in order that any subsequent actions can be planned accordingly.

[2] 'Each visit' refers to visits that are >2weeks apart or those directly following severe weather occurrences.

		B	Injection Transformers	Visual assessment as 1A	Each visit	TE	FLIR/iPhone FLIR		
				Check tightness of bolted terminations	During quarterly scheduled inspection ONLY when Test-rig is isolated	TE	Calibrated torques wrench, socket set and spanners		
		C	PSUs (x5)	Visual assessment as 1A	Each visit	TE	FLIR/iPhone FLIR		
				6 monthly OEM Service inspection	Scheduled w/ REO	Any	REO require Min 2 week notice. (If fully disco'd: 4 units in 8 hours, w/ reconnection by EATL staff)		
		D	PSU control / measuring equipment	Visual assessment of cables, components and terminations Check only for signs of damage or overheating	Each visit	TE	FLIR/iPhone FLIR		
				PAT checks	Scheduled w/ FMS	FMS/ DC/ NJH	PAT Instrument		
		E	Porta-cabin thermo-couples	Visual assessment. Check in place and undamaged, and readings are similar	Each visit	TE			

		F	Data Logger, CEM units, PC / laptop	Visual assessment. Check in place and undamaged, w/ no disconnected wires.	Each visit	TE			
				PAT checks	Scheduled w/ FMS	FMS/ DC/ NJH	PAT Instrument		
		G	E-stop & Fire alarm circuit	Functional assessment and test of local operation and detectors	6 months	TE	?		
				Functional assessment and test of remote operation	6 months	TE	?		
		H	32A Radial circuits and consumer unit	Visual assessment of PSU isolators, sockets and extension cables (incl. mechanical switch operation)	Each visit. Switched operational checks ONLY when convenient	TE	FLIR/iPhone FLIR		
		I	Office furniture	Visual assessment of chair functionality and table legs	Each visit	TE			

2	Test-rig control & monitoring equipment (Outdoor)	A	OHL Thermo-couples	Visual assessment of self-amalgamating tape, and cable insulation material localised to ducted elbows at height and all glanded entry ports.	From ground level each visit.	TE	OHL_PGP[3] / Genie boom/ UAV		
					Review remotely using webcam.				
		B	2D Anemometer	Visual assessment of anemometer sensor head and overall cable insulation material, specifically at all glanded entry ports.	From ground level each visit.	TE	OHL_PGP / Genie boom/ UAV		
					Review remotely using webcam.				
		C	3D Anemometer	Visual assessment of anemometer sensor head and overall cable insulation material, specifically at all glanded entry ports.	From ground level each visit.	TE	OHL_PGP / Genie boom/ UAV		
					Review remotely using webcam.	Any			

[3] 'OHL_PGP' is the OHL fibreglass poles with a GoPro Camera attached at the upper end

		D	Rain Tipping bucket	Visual assessment of functionality and overall cable insulation material, specifically at all glanded entry ports. Cleaning only if required.	Each visit.	TE			
		E	Solar meters	Visual assessment of sensor head and overall cable insulation material, specifically at all glanded entry ports.	Visual assessment and clean each visit.	TE			
		F	Ambient temp probes and radiation shields	Visual assessment of assembly and overall cable insulation material, specifically at all glanded entry ports.	From ground level each visit.	TE	OHL_PGP / Genie boom/ UAV		
					Review remotely using webcam.	Any			
		G	Auxiliary Cabinets	Check condition and functionality of cabinet, door, seals, mountings & panel keys, and identify any evidence of moisture ingress.	Only external inspection performed EVERY visit; detailed checks performed maximum fortnightly visit	TE			

		H	Ducting & trunking	Visual assessment of material, joints and all cable entry ports. Ensure duct seals are functional. Check that there is no pooled water present within, or evidence of rodent activity.	Only external inspection performed EVERY visit; detailed checks performed maximum fortnightly visit	TE			
3	Porta-cabin	A	Fixtures, fittings, windows, door locks & cable entry ports	Confirm condition, functionality, seals and security. Identify any evidence of moisture ingress. Assess functionality/ integrity of cable entry ports and vermin barriers. Assess vermin traps.	Only external inspection performed EVERY visit; detailed checks performed maximum fortnightly visit	TE			
		B	2-step platform	Visual assessment	3 months	TE	FMS		
		C	Entrance steps	Visual assessment	Each visit	TE			

		D	Fire extinguisher	Quarterly inspection	3 months	TE	FMS		
		E	General	Housekeeping	Each visit	All			
4	OHL	A	OHL conductors and fittings	Visual assessment	From ground level each visit.	TE	FLIR/iPhone FLIR OHL_PGP / Genie boom/ UAV		
					Review remotely using webcam.				
		B	Poles, cross-arms and stay-wires	Visual assessment	From ground level each visit.	TE	OHL_PGP / Genie boom/ UAV		
					Review remotely using webcam.				
5	Electricity supply	A	WPD cabling supply to Test-site	No control measures available					
		B	Contract w/ Electricity Supplier (Npower)	Assess actual usage against estimated. Current contract expires: 14/02/17	Review of most appropriate contract	Any		PT	
		C	Cut-out / meter cubicle	Check condition and functionality of cabinet, door, seals, mountings & panel key, and identify any evidence of moisture ingress.	Only external inspection performed EVERY visit; detailed checks performed maximum fortnightly visit	TE			

		D	Internal electrical installation	RCCD test	Quarterly ONLY when possible	TE			
				Annual Test & Inspection	Annual	AJ Electrics		PT	
		E	Earthing	Confirm condition and security of cable and terminations	Only external inspection performed EVERY visit; detailed checks performed maximum fortnightly visit	TE	Hand tools		
6	Fencing/ Gates	A	Fencing & gates	Visual assessment of fixings	Each visit	Any			
		B	Padlock / keys	Confirm functionality	Each visit	TE			
7	Test-site	A	Signage	Visual assessment of condition & fixings	Each visit	Any	Hand tools Cable-ties		
		B	Safety walkway	Visual assessment	Each visit	Any			
		C	Grass maintenance	Ensure maintenance contract works are performed to WPD expectations	Confirm w/ WPD	TE	Maintenance contract		
		D	General house-keeping	Collection & disposal of wind-blown debris/ refuse	Each visit	All			

Appendix V Calendar of Scheduled Project Events

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
Date	Person Responsible	Problem/Action/Event/Comment	Target Completion Date	Results
04/01/2016	MPB	Test data gathering commenced	-	-
25/01/2016	PT	Renewed Electricity Supply Contract w/ Npower (Expires: 14/02/16)	01/02/16	Complete
21/01/2016	NJH/RA/GDC	Visit to Stoke to continue w/ commissioning tasks (Poss. perform 1st Visual Inspection?)	-	Visit performed: outstanding tasks and first inspection partially complete
03/02/16	NH/RA	Logger stopped at 07.14am 02/02/16. Manually restarted: 26hrs of data lost.		
04/02/16	IH	Visit to Test-rig to retrieve Squirrel Logger; passed to AW for repair	-	
06/02/16	NH/RA	Logger stopped at 20.35pm 05/02/01. Manually restarted: 14hrs of data lost.	-	
10/02/16	NH/RA/GPC	Logger firmware updated 10/02/16. Fix firmware bugs, improved operational stability. Continued w/ commissioning tasks (Completed 1st Visual Inspection)	-	
14/02/16	NH/RA	Logger stopped at 15.20pm 14/02/16. Manually restarted: 43hrs of data lost. Configuration issues resulting from logger firmware update. Fixed. Swapped thermocouples. RA on Camera Monitor	-	
16/02/16	-	PSU3 Variac stopped moving	-	
24/02/2016	JDC/NJH	Visit to Stoke to investigate PSU3 Variac issue plus continue w/ commissioning tasks (Complete 1st Visual Inspection?)	24/02/2016	Mods made to proximity switches by JDC

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
10/05/16	NJH	Nick visited site to reset rig after Cabin over-temp trip (>40ºC) had operated on Sunday. No email alerts had been received. Squirrel alarm still not functional. Only noticed by MPB after he returned to work on Tuesday. U/S 12" fan brought back to Capo.	-	Nick performed other tasks whilst on site.
1/05/2016	PT	Schedule 6mth maint. inspection of PSUs w/ REO and EATL resources/visit. Ensure they check the mods JDC made to all PSUs incl. spare. EM sent to REO by PT 240516	1/06/2016	REO to visit site on 06/07/16
07/06/16	PT/JDC	Post-fire visit to assess damage and commence clean-up.	-	Team meeting arranged for 13/06/16
22/06/16	PT/NJH	Site visit to continue reparation tasks	-	
23/06/16	PT/NJH	Site visit to continue reparation tasks	-	Team meeting arranged for 20/06/16
30/06/16	SG	Take PSUs to REO	-	Team meeting arranged for 30/06/16
05/07/16	PT/RG	Site visit to continue reparation tasks	-	
06/07/16	PT/JK	Site visit to continue reparation tasks	-	
06/07/16	REO	Inspection and Service of all 5 PSUs (See update EM from Steve Hughes 11/07/16)		Team meeting arranged for 14/07/16
15/07/16	AJ Electrics	Complete the replacement of Fire Alarm smoke detector and perform Fixed Electrical Installation Inspection (Retest was originally due: 06/03/16)	-	
18/07/16	PT/JDC/JK	Commence testing of PSUs, IT 1 & 4 and all new ancillary control modules at Capenhurst		

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
w/c 25/07/16	PT/JDC/JK	Transport all equipment to Stoke and re-commission.	-	
w/c 01/08/16	PT/JDC	Final re-commissioning tasks performed (2nd & 4th Aug). Rig fully re-commissioned and logging data as of COP 04/08/16.	-	
8/08/16	NJH	Restart Datataker logger at Stoke	-	
10/08/16	NJH	Restart Datataker logger at Stoke	-	
15/08/16	MPB/NJH	Restart Datataker logger at Stoke w/ tele-assistance from OMNI: OMNI claim that the internal main battery is the most likely cause of the fault. I discussed issue w/ Steve (Omni) on phone…. Awaiting response.	-	
17/08/16	NJH	Restart Datataker logger at Stoke		
22/08/16	PT	Received pre-programmed DT85 from Omni. Went to Stoke and replaced 'suspect' unit. Replacement unit logger appears susceptible to the same fault as the 'suspect' DT85. Discussed w/ Omni and Mark (Grant Instruments). Andy and Mark (GI) will scrutinise programme line-by-line during next 2 days. Comms w/ DT85 intermittent/unreliable, therefore, the PSUs to the OHL rigs were not energised.	-	
26/08/16	PT	Solo visit to Stoke at request of OMNI. Rebooted 'loan' logger successfully. Andy Omni remotely cleared the existing program completely and all old data from logger. He suspects that:		

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
		• The existing program may have been causing stoppage of the command screen • The latest firmware version may have also contributed to problem He then loaded new modified program and monitored for an hour or so. Andy is going to: • Discuss the issues again with Datataker/Mark (Grant Instruments) today • Monitor the logger remotely during the next 2-3 days (There is no bank holiday next week in Scotland). As the comms w/ DT85 were intermittent/unreliable the PSUs to the OHL rigs were not energised.		
03/09/16	RA	Solo visit to Stoke on way to London: • Reboot logger • Install new Ethernet s/w • Confirm all LAN/comms cabling between Ethernet s/w, logger, wifi and PC • Install temp. DC supply feeding Squirrel to test supply voltage stability • Photograph all connections for records		
08/09/16	MPB	Solo visit to Stoke: • Installed a new power supply adapter to the Datataker DT85-3 logger. • Installed the new internet based Power Cycle Box to the Data logger, to restart in case it crashes • Checked and confirmed the operation of the power cycle box • Turned the rig power supplies back on. • Ramiz A confirmed access to logger remotely. • Richard Ash changed the settings of the internet router to only allow EA Technology IP address to connect to the logger (reducing external interference). This does not affect the cameras (still accessible via iPhone app). • The rig is now back on and operational……		

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
22/09/16	JDC/MPB	Visited Test-rig: 1. Adjusted PSU auto control current settings after calibration factors have been properly determined by JDC and MPB. 2. Taped up PS cable plug to DT85 to ensure connection is sound 3. Collected spare loan DT85 Logger (and grommet) 4. Repaired cable termination fault at power supply to WindMaster	-	
07/11/16	NJH	Visited Test-rig to: 1. De-energised test-rig and accompanied NPower whilst they replaced faulty electricity meter. Then re-energised test-rig. 2. Collected green DT85 connectors to return to Omni. 3. Installed new 24V supply to DT85[4] (See notes in "Outstanding tasks"). 4. Filled in rodent hole nr electricity meter box cable duct (hockey-stick). 5. Lubricated porta-cabin entrance door plate, locking mechanism & hinges. 6. Inspected all Test-rig control equipment located in porta-cabin using FLIR cam. 7. Completed new Maintenance Inspection Check-sheet. 8. With assistance from WPD MEWP, reassemble 2 TCs on Rig 1 CCT 4 (Ash) due to measurement inaccuracy and check all TCs on Rig 1 CCT 4 (Ash) conductor are correctly identified (Discuss w/ MPB first). RW: Liaise w/ WPD for MEWP access. Activity to be performed during next visit. MPB stated not necessary w/c 31/10/16. 9. Used wall heater whilst onsite; seemed ok.	-	Complete
Jan 2017	PT	Confirmed Electricity Supply Contract renewal w/ Npower (Was due to expire: 15/02/17) Price comparison checks performed via telephone with representatives of quotemyenergy.co.uk, LoveEnergySavings.com, and npower. Npower's 24mth		Completed

[4] Re-install DT85 internal-battery-link upon arrival at site in order to charge internal battery for 1h duration prior to replacing suspect 12V power supply with new 24V power supply. Ensure to remove internal-battery-link from DT85 once new 24V PS is installed.

Calendar of Scheduled Events 2016/17		Last updated: 01/07/17		
		contract offered the most competitive value. Signed up for next 2 years as of 13/01/17.		
16/01/17	NJH/RA/MPB	Visit site to work on anemometer from MEWP and perform PAT testing on appropriate equipt.		Completed
02/01/2017	~~PT~~ JDC/NJH	6mth maintenance inspection and contact brush replacement of REO PSUs scheduled for w/c 27/03/17. Spare brush sets received from REO 20/03/17. [REO stated (on 24/06/16) that they will provide spares and a Work Instruction (WI) in order that EATL can perform the next inspection(s). Maintenance date reflects re-energisation of rig c08/09/16] Re-calibration of Current-sensors to be performed during same visit.	1/03/2017	WIP
Mar 2017	PT	Prepare Site Decommission Method Statement: Deco Statement planning has commenced between PT & RW. RW to discuss various potential options considered with appropriate parties in due course.	July 2017	Ongoing
Mar 2017	PT	PO for 'Grounds maintenance' for 2017 placed with Hortech on 14/03/17.		WIP
1/07/2017	PT	Schedule 6mth maint. inspection of PSUs by EATL/REO	1/09/2016	
1/09/2017 (TBC)	PT/REO/TE	6mth maint. inspection of PSUs by EATL/REO		
Jan 2018		Stop gathering test data		
Mar 2018	PT	Decommission Test-rig and Site	June 2018	
July 2018	MPB	Produce Final Report		
July 2018		Site Lease Expires		

Appendix VI Revised Solar Heating Calculation for CIGRÉ Technical Brochure TB601

Solar heating calculation used in OHTEMP2. MPB revision of Section 3.3 of CIGRÉ Technical Brochure TB601, "Guide for thermal rating calculations of overhead lines" (2014). Numbers in square brackets indicate references in original TB601.

Solar heating calculation

The solar heat gain per unit length by a conductor, P_S (W/m), is directly proportional to the outer diameter of the conductor, D (m), the absorptivity of the surface of the conductor, α_S, and the global radiation intensity I_T (W/m^2) [23]:

$$P_S = \alpha_S \cdot I_T \cdot D \qquad (8)$$

The value of α_S varies from around 0.2 for a bright new conductor to around 0.9 for a weathered conductor in an industrial environment [17, 5]. A new conductor in a heavy industrial environment weathers to around α_S = 0.5 after about one month's exposure, and to around α_S = 0.9 after about one year. The rate of weathering is slower in rural areas. It is not easy to measure the absorptivity accurately. The recommended methods are either determining the emissivity of the conductor, by measuring samples and then estimating absorptivity to be slightly higher than this value (0.1 – 0.2 higher), or using a default absorptivity of no less than 0.8 [5].

Devices for measuring global radiation intensity I_T are relatively inexpensive and reliable, and can be easily used for line monitoring systems [64], as they can provide measurements of the mean global radiation intensity for a period of time for the dynamic thermal rating calculations. But there are some considerations that have to be noted. The global radiation received by the conductor is not necessarily the same at all points along the line. It depends on the location, and important differences may arise due to different orientation, sheltered areas, reflectance from ground, etc. The variability with time is also not the same at all points along the line.

For planning or design, it is common to consider a "worst-case" situation, for which the maximum expected value of the global radiation I_T can be anticipated. Care must be taken in anticipating the right values, and their coincidence with other ambient parameters [5]. A value can be estimated for a given location and orientation of the line, and for a specific time and day of the year, from the relative position of the sun (see the formulae below).

The global radiation intensity, I_T, is a combination of the direct solar radiation on a surface normal to the beam, I_B, the diffuse sky radiation to a horizontal surface, I_d, and the incident radiation reflected from the ground or albedo, F. The formula for the total solar power received per unit length of the conductor P_S (W/m) is given by [19, 23, 29]:

$$P_S = \alpha_S \cdot D \cdot \left[I_B \cdot \left(sin(\eta) + \frac{\pi}{2} \cdot F \cdot sin(H_S) \right) + I_d \cdot \left(1 + \frac{\pi}{2} \cdot F \right) \right] \qquad (9)$$

where:

α_S = absorptivity of conductor surface (see the text above)

D = diameter of the conductor (m)

I_B = direct (beam) solar radiation intensity (W/m^2)

η = the angle of solar beam with respect to the axis of the conductor

F = the albedo or reflectance of the ground

H_S is the solar altitude, the height of the sun above the horizon.

An equation to calculate the direct solar radiation at sea level, $I_{B(0)}$, is [66]:

$$I_{B(0)} = N_S \cdot \frac{1280 \cdot sin(H_S)}{sin(H_S) + 0.314} \quad (10)$$

where N_S is a clearness ratio, having the value of 1.0 for the standard atmosphere, 0.8 to 1.2 for clear skies with decreasing amounts of dust and aerosols, 0.5 for an industrial atmosphere and less than 0.5 for a cloudy or overcast sky. With thick cloud, N_S = 0. The direct beam irradiation I_B increases with increasing height above sea level, y, according to the following equation [67]:

$$I_{B(y)} = I_{B(0)} \cdot \left[1 + 1.4 \cdot 10^{-4} \cdot y \cdot \left(\frac{1367}{I_{B(0)}} - 1\right)\right] \quad (11)$$

H_S is given by:

	H_s	= arcsin(sinδ_s.sinφ + cosδ_s.cosφ.cosZ)			(12a)				
where	δ_s	Solar Declination (angle between equator and a line drawn from centre of the Earth to centre of the sun)	=	23.45xsin(360(284+N*)/365)	(12b)				
	φ	= Latitude (+ to North)							

	Z	is the Hour Angle (angle between the sun's position and its noon position)	=	15x24 (LST-LT0)-180	(12c)
and	N*	Day Number	=	day of the year (Jan 1st = 1)	
where	LST	Local Solar Time (local time adjusted for longitude and time zone)	=	LT+TC/(24x60)	(12d)
	LT	Local Time (clock time)	=	dd/mm/yyyy hh:mm:ss	(12e)
	LT0	Reference Time (previous midnight)	=	dd/mm/yyyy 00:00:00	(12f)
	TC	Longitude Time Correction Factor	=	4(ϑ-LSTM)+EoT	(12g)
where	ϑ	= Longitude (+ to E)			
	TZ	Time Zone (+ to East) - local time minus GMT in h	=	LT - GMT	(12h)
	LSTM	Local Std Time Meridian (angular correction for TZ)	=	15 TZ	(12i)
	EoT	Equation of Time (corrects for Earth's axial tilt and orbital eccentricity)	=	9.87 sin(2B)-7.53 cos(B)-1.5 sin(B)	(12j)
	B	EoT angular parameter	=	360(N-81)/365	(12k)

I_d is the diffuse solar radiation intensity (W/m^2). There is a correlation between direct irradiation I_B and diffuse irradiation I_d, as clouds cause both a reduction in I_B and an increase in I_d. An equation to calculate the diffuse irradiation for all skies is [68]:

$$I_d = (430.5 - 0.3288 \cdot I_B) \cdot sin(H_S) \quad (13)$$

η, the angle of the solar beam with respect to the axis of the conductor is given by:

$$\eta = arccos[cos(H_s) \cdot \cos(\gamma_S - \gamma_C)] \quad (14)$$

where:

γ_S = Solar Azimuth (angle between Sun and N)

γ_C = azimuth of the conductor (angle between conductor and N)

Care is necessary when calculating the Solar Azimuth, $\boldsymbol{\gamma_S}$. It is a function of, but is not necessarily equal to, the Solar Azimuth parameter, $\boldsymbol{\gamma_p}$, see below. Ignoring this fact will produce some very strange results, like the sun moving backwards across the sky at certain times of the day!

	γ_p	solar azimuth parameter (rel. to N)		=	$\arccos[(\sin\delta.\cos\varphi - \cos\delta.\sin\varphi.\cos Z)/\cos\alpha]$	(14a)
	γ_S	solar azimuth (rel. to N)		=	γ_p or $(360- \gamma_p)$ depending on hour angle Z	(14b)
		Z less than -180	γ_S	=	$360 - \gamma_p$	(14c)
		Z between -180 and 0	γ_S	=	γ_p	(14d)
		Z between 0 and 180	γ_S	=	$360 - \gamma_p$	(14e)
		Z greater than 180	γ_S	=	γ_p	(14f)

F is the albedo or reflectance of the ground. The albedo F is approximately 0.05 for a water surface ($H_S > 30^\circ$), 0.1 for forests, 0.15 for urban areas, 0.2 for soil, grass and crops, 0.3 for sand, 0.4 to 0.6 for ice and 0.6 to 0.8 for snow. The albedo tends to increase as the solar altitude H_S increases.

The residual gain at night can be considered negligible.