NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

JUNE 2017

ANGLE-DC

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Table of Contents

SECTION 1 EXECUTIVE SUMMARY

1.1. Project Background

The Angle-DC project is funded through Ofgem's Network Innovation Competition. Angle-DC commenced in January 2016 and will be completed by April 2020. The project will demonstrate a smart and flexible method for reinforcing distribution networks by converting Alternating Current assets for Direct Current operation. Angle-DC will adapt existing power electronic technologies to build a Medium Voltage Direct Current link which could be an effective solution to facilitate the integration of renewable resources and accommodate future demand growth.

This report details the progress of the Angle-DC project, focusing on the 3rd 6-month period of the project, January to June 2017. It also details work due to be carried out in H2 2017.

1.2. Project Progress Highlights

The overall project is divided into 6 distinct work packages and the Project's managers' report separates the project progress by these key areas.

The project has held three Steering Board meetings; in June and November 2016 and June 2017. Cardiff University have continued their academic work in two key areas: released generator headroom and MVDC converter control schemes and published three CIRED 2017 conference papers based on this work.

Work Package 1 – Detailed Design

The contracting stage for the Medium Voltage Direct Current converters has been completed. A contract between GE Energy and SP Energy Networks was signed in March 2017. Detailed engineering design by GE Energy has begun, with the required building specification taking early priority.

The acoustic survey results for both sites has been shared with the Environmental Health teams of both Anglesey and Gwynedd councils and background noise levels have been agreed between SP Energy Networks and the two councils. SP Energy Networks will assume conservative noise levels from noise producing equipment and design in mitigations into the building layout and design.

SP Energy networks held a Hazard Identification (HAZID) workshop with all Britannia Bridge safety case stakeholders which identified all foreseeable rail hazards arising from the AC to DC conversion. SP Energy Networks and Frazer Nash Consulting presented to the Network Rail Engineering System Review Panel (E-SRP), who approved the approach being taken under the Common Safety Method Process. Both the HAZID workshop and E-SRP presentation took place in May 2017.

An internal workshop was held in March 2017 with internal experts within SP Energy Networks, which included staff from Real Time Systems (RTS) and Network Control. Feedback was gathered from these internal experts, which has been fed into the local and central control strategies. The tender process for the local and central control supply has been moved to mid-

2017 to incorporate the feedback from external suppliers and internal expertise with SP Energy Networks.

Work Package 2 – MVDC Link

Following the converter contract signing in March 2017, SPEN has held 2 design meetings with GE Energy, to finalise the converter buildings specification. Early building design approval will minimise any delay in commissioning follow the converter Factory Acceptance Tests (FATs). The converter detailed design and fabrication will continue until H2 2018.

Work Package 3 – AC System

Iberdrola Engineering and Construction (IEC) have begun the internal tender development work for the procurement of the back-up AC circuit. This should be complete in July 2017, with the tender opening to suppliers in H2 2017. Substation, Bridge and cable route surveys have taken place in May 2017 to inform the development of the tender documentation. Discussions with Network Rail regarding consents have continued to progress.

Work Package 4 – Holistic Cable Condition Monitoring System

Monitoring system equipment installation was completed in in Q1 2017, with the energisation of the Kronos cabinets and system server. The system began offline monitoring in January 2017 and HVPD have collected the first set of AC Partial Discharge results. A temporary GPRS modem will be installed by the end of H1 2017 to allow online monitoring.

Work Package 6 – Knowledge Dissemination

During Q1 2017, the Angle-DC project presented at the IET 13th international conference on AC and DC Power Transmission. Cardiff University and SP Energy Networks submitted a total of four conference papers to various conferences. A synopsise to CIGRE 2018 was also submitted and accepted in April 2017. During this period, the project held a workshop and a webinar. A recording of the webinar has been made available to the public via the Angle-DC website.

1.3. Business Case

As of June 2017, there has been no change to the business case of the project. The results from the Common Safety Method Risk Assessment and Evaluation on Electromagnetic Interference are still being progressed and shall inform any amendments to the business case should approval by Network Rail not be possible.

1.4. Learning Outcomes

Learning points are reviewed by the Angle-DC Project team at regular meetings to establish what was learned from the activities undertaken. At this stage early stage of the project, no formal learning outcomes have been published. The following learning outcomes are detailed in Section 8 of this report:

Potential of Electromagnetic Interference (EMI) Safety Case: The CSM REA approach to safety is acceptable to the Network Rail E-SRP based on the Hazards identified at the HAZID workshop.

1.5. Key Risks

At this stage, many of the risks have not had time to arise but still have an opportunity to do so. Section 10 of this report contains the current risks associated with successfully delivering Angle - DC as captured in the Risk Register including the risks captured in the last six-months.

The risk associated with gaining Network Rail approval is still outstanding but has been reduced through engagement at the E-SRP meeting and HAZID workshop. There are still areas of significant uncertainty. Laying a new section of circuit, using directional drilling under the Menai Strait, may still be required should the EMI study show the converted circuit cannot achieve compliance on the Bridge . The costs for this option would be significantly higher than for the Britannia Bridge route.

SECTION 2 PROJECT MANAGER'S REPORT

The last six months period has seen progress in a number of areas against the plan. The overall project is divided into 6 distinct work packages which enable the Angle-DC solution and provide valuable learning to the UK electricity industry. The progress and details of each of the work packages is set out in this section.

2.1. Work Package 1 – Detailed Design

During the 3rd 6-month period of the project, progress has been made in four key areas, these are: progress on the Common Safety Method Risk Evaluation and Assessment (CSM-REA), modelling an alternative basis for a local controller, completion of the technical specification for the Medium Voltage Direct Current (MVDC) converters and completion of acoustic survey reports at Llanfair and Bangor Grid substations.

2.1.1 Progress - Common Safety Method Risk Assessment

The start of Phase I began in early March 2017 following contract awards to three specialist suppliers: The Common Safety Method Risk Assessor (CSM RA), The Assessment Body (AB) and the Electromagnetic Compatibility (EMC) modelling supplier. The Phase I work began with an expert stakeholder kick off meeting, followed by a Hazard Identification (HAZID) workshop. In May 2017, the planned safety approach, presented to the Network Rail Engineering System Review Panel (E-SRP), was met with approval. The first round of safety documentation has also been approved by Network Rail and the Assessment Body, which consists of: The System Safety Plan, The System Definition and the Hazard Identification (HAZID) Workshop Report.

The next stages of work will involve detailed modelling of the bridge electromagnetic environment, focused on Hazards identified at the HAZID workshop. The Phase I program of works is planned to be concluded by July 2017. This may be extended to August 2017 to give time to present the CSM-REA safety justification report to the E-SRP, where a decision on interim approval will be given.

Phase II work will seek to provide demonstration of compliance with safety requirements through testing and validation of EMI models and safety requirement assumptions. The Phase II work will be carried out as part of the converter commissioning in December 2018.

2.1.2 Alternative Basis – Local Control

During an internal workshop with engineering experts within SPEN, an alternative basis for a local controller was suggested, which requires a less extensive and therefore more robust communications network. TNEI have carried out a study assessing whether a similar optimum setpoint point calculation approach could be based on local feeder monitoring at Llanfair PG instead of monitoring at the 3 Primary Grid Transformers on Anglesey, as was originally assessed.

Findings from the report conclude this option, although less expensive, cannot ensure the network remains within its N-1 operational envelope due to inappropriate island boundary conditions for monitoring. The study did provide a recommendation for a basic control setpoint under the original grid transformer monitoring basis, should central control communication be lost. A constant 10MW import to Anglesey would not breach the N-1 network operational envelope and would be close to the optimum converter setting for most of the time. This finding was on based on 1-year (2015-16) of PI Historian data. This means the DC link will be utilised whatever the control mode of the MVDC link.

A Scope of Works (SoWs) document, for the supply of a local controller, is to be updated before issue to suppliers. Technical evaluation and supplier selection will take place during H2 2017 to allow for input by SPEN Real Time Systems (RTS). The local controller will be developed by the supplier, ready for installation and testing in H2 2018.

2.1.3 Development of Technical Specifications

The Technical Specification for the MVDC converters was published on the Angle-DC website during February 2017 to meet Successful Delivery Reward Criteria (SDRC) 2.

2.1.4 Acoustic Survey

Following the presentation of the acoustic survey results to both Anglesey and Gwynedd council Environmental Health Officers, agreed noise limits for the two converter station sites were reached.

Discussions with GE Energy connections revealed that accurate octave band values for converter station equipment cannot be known before the converter is in operation. SPEN will therefore assume conservative values for the noise propagation assessment and allow for sufficient levels of sound insulation in the building design, which is due to be complete in Q3 2017.

2.2. Work Package 2 – MVDC Link

SPEN has drafted the MVDC converter procurement contract, with the selected supplier GE Energy Connections. This work was concluded in March 2017. Following signing, the converter detailed design phase is now taking place. The converter building lies on the critical path for the project, so early design meetings with GE have focused on developing the building specification based on layout and other design decisions made by SPEN.

Following the finalisation of the building specification by GE, IEC will work with a building environmental modelling supplier to specify and design a building that meets the converter operational specification. This design will form the basis of a tender for the supply of the converter station buildings. It is expected the tender will be opened to suppliers by IEC in Q3 2017.

2.3. Work Package 3 – AC System

Iberdrola Engineering and Construction (IEC) have begun their program of works. Surveys on the Britannia Bridge have been carried out with Network Rail for the AC back up circuit and a contractor for the cable trail holes is being procured.

During Q3 2017, IEC will finalise the AC circuit tender design and open the tender process to suppliers for the provision of the AC cable and switchgear. During Q4, the suppliers should be selected, ready to begin manufacturing and installation during Q1 2018.

2.4. Work Package 4 – Holistic Circuit Condition Monitoring System

Monitoring system equipment installation was completed in in Q1 2017, with the energisation of the Kronos cabinets and system server. The system began offline monitoring in January 2017 and HVPD have collected the first set of AC Partial Discharge results. A temporary GPRS modem will be installed by the end of H1 2017 to allow online monitoring with Partial Discharge alarms.

HVPD will carry out system diagnostics in Q3 2017 using monitoring data already being recorded onsite.

2.5. Work Package 5 – Data Analysis and Enhanced Learning

Collection of HCCM data will form a part of Work Package 5. This data will be analysed and interpreted by the HCCM supplier HVPD and then reviewed by SPEN. This work has begun ahead of schedule with the first analysis and results due in June 2018.

2.6. Work Package 6 – Knowledge Dissemination

During February 2017, the Angle-DC project was present at the IET 13th international conference on AC and DC Power Transmission, where the project presented two papers, generating a high level of interest. During H1 2017, Cardiff University and SP Energy Networks submitted at total of four conference papers to CIRED 2017 and have registered for interactive posters sessions at the event. A synopsise to CIGRE 2018 was submitted and accepted in April 2017.

A webinar on MVDC technology and supplier engagement, followed by a workshop on MVDC converter technical design, took place in March and April 2017. The webinar recording was made available on the Angle-DC website. During June 2017, the Project presented a general over view paper in the form of an interactive poster session. During Q1 2017, Cardiff University submitted two conference papers to CIRED 2017 based on their work. Cardiff University will be presenting their papers at the CIRED conference.

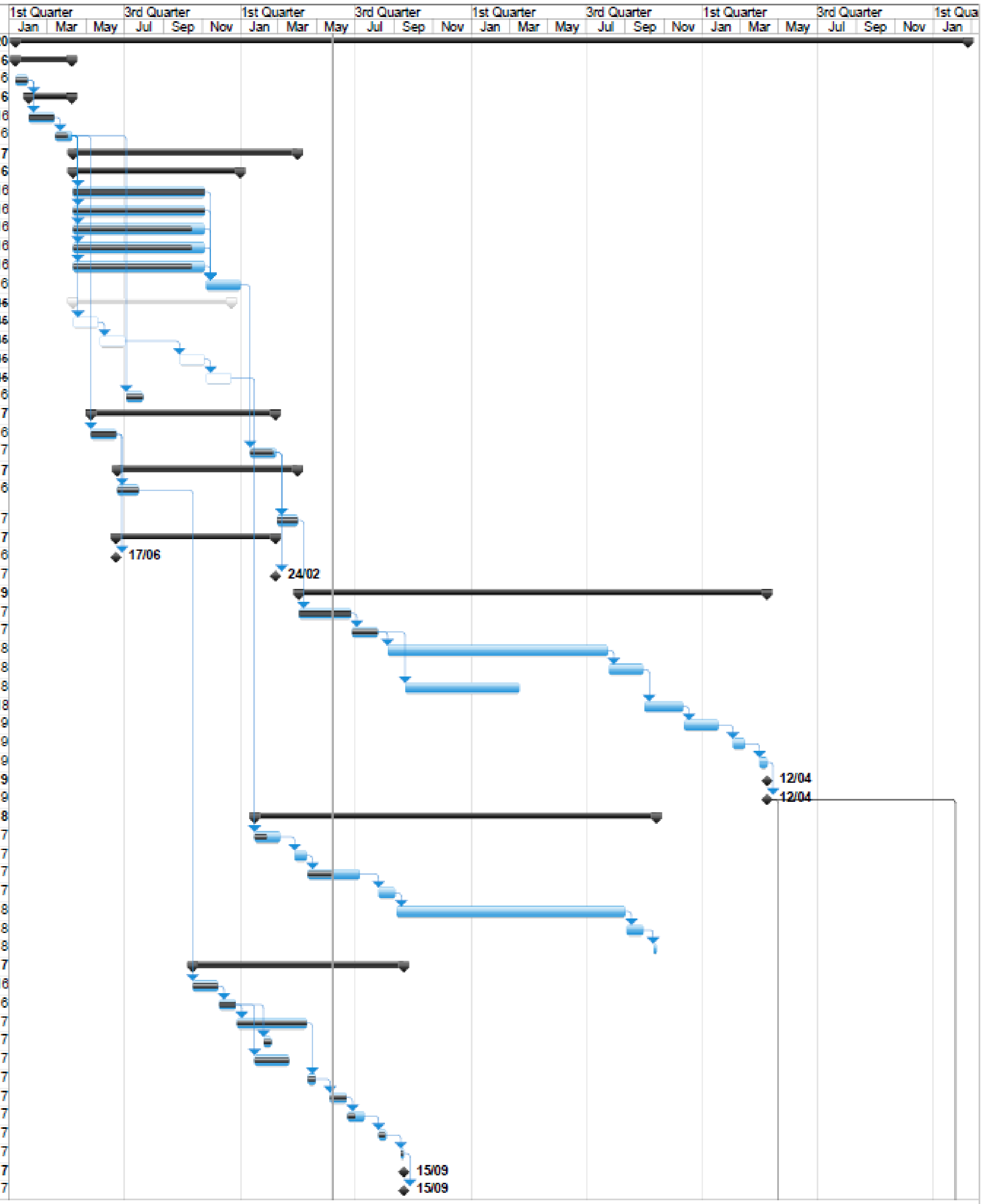
A detailed synopsis, produced by the Project, has been issued to the UK working group for CIGRE 2018. The selection results will be announced in October 2017. In November 2017, the Project will present its second webinar on Real-Time Circuit Condition Monitoring systems for AC and DC applications to interested stakeholders. Cardiff University will also be submitting their paper on particle swarm optimisation to the Conference on Applied Energy in H2 2017.

SECTION 3 BUSINESS CASE UPDATE

To date there has been no change to the business case of the project. The cost for both the HCCM systems and MVDC link are now known. At this stage, no amendments to the business case are required. In the next 6-months, findings from the CSM-REA should provide some indication of any required changes.

SECTION 4 PROGRESS AGAINST PLAN

ID	Info	Task Name	Duration	Start	Finish
1		**ANGLE-DC**	**1077 days**	**Mon 11/01/16**	**Mon 24/02/20**
2		**Project setup**	**65 days**	**Mon 11/01/16**	**Fri 08/04/16**
3	✓	Project initiation document	15 days	Mon 11/01/16	Fri 29/01/16
4		**Formalise team structure: Project manager, Project board, Delivery team**	**50 days**	**Mon 01/02/16**	**Fri 08/04/16**
5	✓	Identify project partners	30 days	Mon 01/02/16	Fri 11/03/16
6		Develop collaboration agreement with project partners	20 days	Mon 14/03/16	Fri 08/04/16
7		**WP1 - Detailed design**	**255 days**	**Mon 11/04/16**	**Fri 31/03/17**
8		**Detailed system analysis**	**190 days**	**Mon 11/04/16**	**Fri 30/12/16**
9	✓	Generation, demand scenarios analysis	150 days	Mon 11/04/16	Fri 04/11/16
10	✓	Normal and fault conditions analysis	150 days	Mon 11/04/16	Fri 04/11/16
11		Harmonic analysis	150 days	Mon 11/04/16	Fri 04/11/16
12		Development of control strategy	150 days	Mon 11/04/16	Fri 04/11/16
13		Development of protection strategy	150 days	Mon 11/04/16	Fri 04/11/16
14		Q&A and approval	40 days	Mon 07/11/16	Fri 30/12/16
15		~~Cable capability evaluation~~	~~180 days~~	~~Mon 11/04/16~~	~~Fri 16/12/16~~
16		~~Development of test specification~~	~~30 days~~	~~Mon 11/04/16~~	~~Fri 20/05/16~~
17		~~Procurement for cable test~~	~~30 days~~	~~Mon 23/05/16~~	~~Fri 01/07/16~~
18		~~Cable capability test~~	~~30 days~~	~~Mon 26/09/16~~	~~Fri 04/11/16~~
19		~~Cable capability evaluation report~~	~~30 days~~	~~Mon 07/11/16~~	~~Fri 16/12/16~~
20	✓	MVDC market research update	20 days	Mon 04/07/16	Fri 29/07/16
21		**Development of technical specifications**	**210 days**	**Mon 09/05/16**	**Fri 24/02/17**
22	✓	Develop holistic condition monitoring equipment technical specification	30 days	Mon 09/05/16	Fri 17/06/16
23		Develop MVDC link technical specification	30 days	Mon 16/01/17	Fri 24/02/17
24	✓	**Develoment of invitation to tender documents**	**205 days**	**Mon 20/06/16**	**Fri 31/03/17**
25	✓	Develop invitation to tender documents for holistic condition monitoring equipment	25 days	Mon 20/06/16	Fri 22/07/16
26	✓	Develop invitation to tender documents for MVDC link	25 days	Mon 27/02/17	Fri 31/03/17
27	✓	**SDRCs**	**180 days**	**Fri 17/06/16**	**Fri 24/02/17**
28	✓	Publication of technical specification for monitoring system	0 days	Fri 17/06/16	Fri 17/06/16
29	✓	Publication of technical specification for the MVDC link	0 days	Fri 24/02/17	Fri 24/02/17
30		**WP2 - MVDC Link**	**530 days**	**Mon 03/04/17**	**Fri 12/04/19**
31	✓	Procurement and vendor evaluation	60 days	Mon 03/04/17	Fri 23/06/17
32	✓	Sign the contract	30 days	Mon 26/06/17	Fri 04/08/17
33		Equipment production	250 days	Mon 21/08/17	Fri 03/08/18
34		Factory acceptance test	40 days	Mon 06/08/18	Fri 28/09/18
35		Site preparation, civil, communications and electrical	130 days	Mon 18/09/17	Fri 16/03/18
36		Equipment delivery	45 days	Mon 01/10/18	Fri 30/11/18
37		Equipment installation	40 days	Mon 03/12/18	Fri 25/01/19
38		Site acceptance test	15 days	Mon 18/02/19	Fri 08/03/19
39		Commissioning	10 days	Mon 01/04/19	Fri 12/04/19
40		**SDRCs**	**0 days**	**Fri 12/04/19**	**Fri 12/04/19**
41		Installation of MVDC link	0 days	Fri 12/04/19	Fri 12/04/19
42		**WP3 - AC System**	**455 days**	**Mon 23/01/17**	**Fri 19/10/18**
43		Detailed circuit design	30 days	Mon 23/01/17	Fri 03/03/17
44		Procurement	15 days	Mon 27/03/17	Fri 14/04/17
45		Wayleaves	60 days	Mon 17/04/17	Fri 07/07/17
46		Equipment delivery	20 days	Mon 07/08/17	Fri 01/09/17
47		Installation	260 days	Mon 04/09/17	Fri 31/08/18
48		Protection settings	20 days	Mon 03/09/18	Fri 28/09/18
49		Commissioning	5 days	Mon 15/10/18	Fri 19/10/18
50		**WP4 - Holistic Condition Monitoring**	**240 days**	**Mon 17/10/16**	**Fri 15/09/17**
51	✓	Procurement and vendor evaluation	30 days	Mon 17/10/16	Fri 25/11/16
52	✓	Sign the contract	20 days	Mon 28/11/16	Fri 23/12/16
53	✓	Equipment production	80 days	Mon 26/12/16	Fri 14/04/17
54	✓	Factory acceptance test	10 days	Mon 06/02/17	Fri 17/02/17
55	✓	Site preparation	40 days	Mon 23/01/17	Fri 17/03/17
56	✓	Equipment delivery	10 days	Mon 17/04/17	Fri 28/04/17
57	✓	Equipment installation	20 days	Mon 22/05/17	Fri 16/06/17
58		Communications	20 days	Mon 19/06/17	Fri 14/07/17
59		Site acceptance test	10 days	Mon 07/08/17	Fri 18/08/17
60		Commissioning	5 days	Mon 11/09/17	Fri 15/09/17
61		**SDRCs**	**0 days**	**Fri 15/09/17**	**Fri 15/09/17**
62		Commissioning of Holistic Condition Monitoring systems	0 days	Fri 15/09/17	Fri 15/09/17

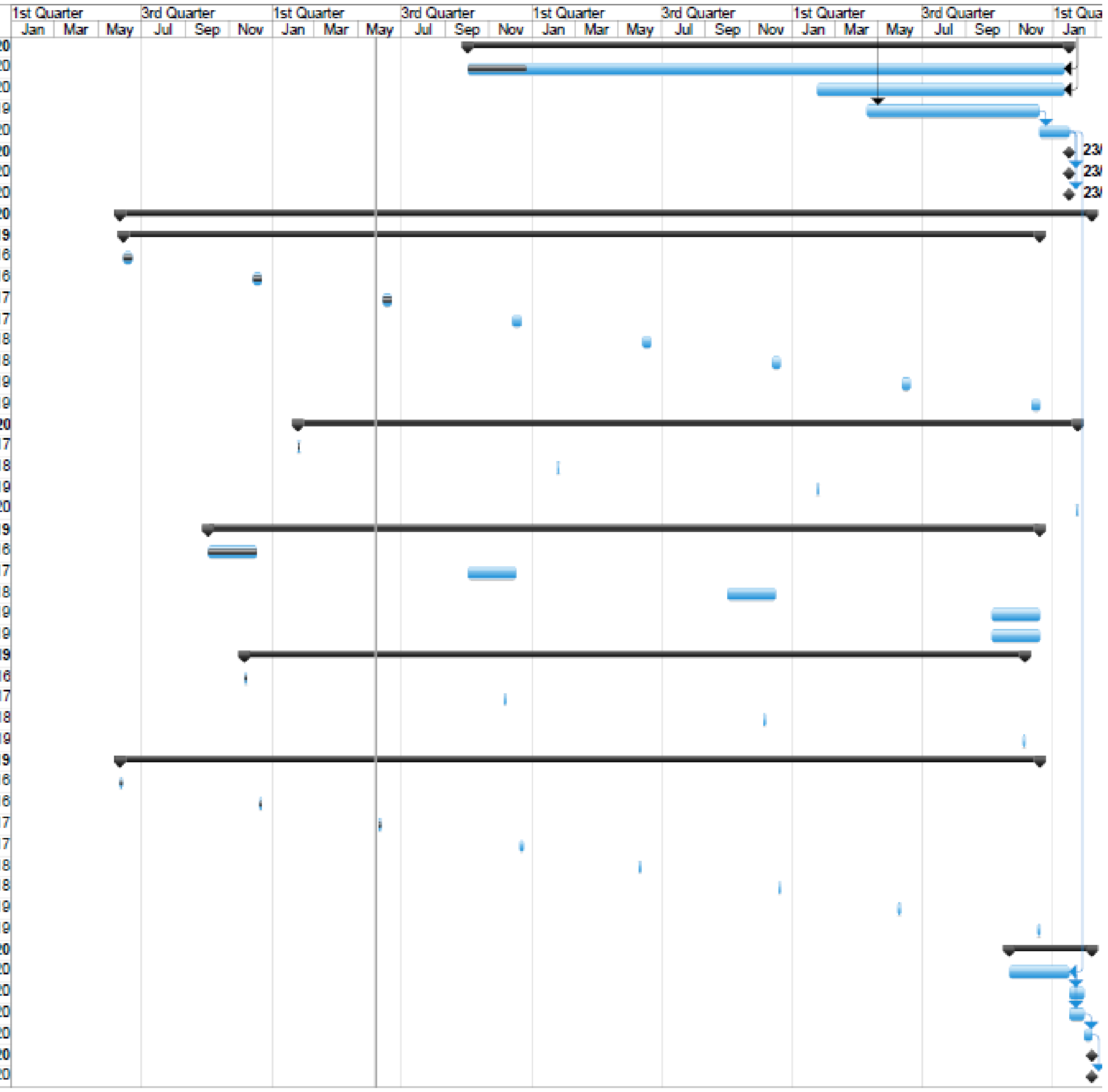


Project: ANGLE-DC Project Plan
Date: Fri 26/05/17

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Progress · Deadline

ANGLE-DC

ID		Task Name	Duration	Start	Finish
63		**WP 5 - Data Analysis**	**605 days**	**Mon 02/10/17**	**Thu 23/01/20**
64		Gather Holistic Condition Monitoring data	600 days	Mon 02/10/17	Thu 16/01/20
65		MVDC system setting adjustments	250 days	Mon 04/02/19	Thu 16/01/20
66		Develop policy documents for MVDC applications	175 days	Mon 15/04/19	Thu 12/12/19
67		Report writing	30 days	Fri 13/12/19	Thu 23/01/20
68		**SDRCs**	**0 days**	**Thu 23/01/20**	**Thu 23/01/20**
69		Publication of Holistic Condition Monitoring data	0 days	Thu 23/01/20	Thu 23/01/20
70		Publication of operation performance of MVDC converters	0 days	Thu 23/01/20	Thu 23/01/20
71		**WP 6 - Dissemination**	**975 days**	**Wed 01/06/16**	**Mon 24/02/20**
72		**6 monthly progress report**	**921 days**	**Mon 06/06/16**	**Fri 13/12/19**
73	✓	Report 1	10 days	Mon 06/06/16	Fri 17/06/16
74	✓	Report 2	10 days	Mon 05/12/16	Fri 16/12/16
75	✓	Report 3	10 days	Mon 05/06/17	Fri 16/06/17
76		Report 4	10 days	Mon 04/12/17	Fri 15/12/17
77		Report 5	10 days	Mon 04/06/18	Fri 15/06/18
78		Report 6	10 days	Mon 03/12/18	Fri 14/12/18
79		Report 7	10 days	Mon 03/06/19	Fri 14/06/19
80		Report 8	10 days	Mon 02/12/19	Fri 13/12/19
81		**Workshops**	**783 days**	**Mon 06/02/17**	**Tue 04/02/20**
82	✓	MVDC Technical Design	2 days	Mon 06/02/17	Tue 07/02/17
83		Real-Time Circuit Condition Monitoring	2 days	Mon 05/02/18	Tue 06/02/18
84		MVDC Manufacturing and Site Preparation	2 days	Mon 04/02/19	Tue 05/02/19
85		MVDC Link Performance Review	2 days	Mon 03/02/20	Tue 04/02/20
86		**Webinars**	**836 days**	**Mon 03/10/16**	**Fri 13/12/19**
87	✓	MVDC technoloigy and Supplier Engagement	50 days	Mon 03/10/16	Fri 09/12/16
88		Real-Time Circuit Condition Monitoring systems for AC and DC applications	50 days	Mon 02/10/17	Fri 08/12/17
89		MVDC manufacturing	50 days	Mon 01/10/18	Fri 07/12/18
90		Cable ageing mechanism in AC and DC conditions	50 days	Mon 07/10/19	Fri 13/12/19
91		MVDC perfomance in real-life and data analysis	50 days	Mon 07/10/19	Fri 13/12/19
92		**LCNI conference**	**784 days**	**Wed 23/11/16**	**Fri 22/11/19**
93	✓	LCNI 2016	3 days	Wed 23/11/16	Fri 25/11/16
94		LCNI 2017	3 days	Wed 22/11/17	Fri 24/11/17
95		LCNI 2018	3 days	Wed 21/11/18	Fri 23/11/18
96		LCNI 2019	3 days	Wed 20/11/19	Fri 22/11/19
97		**SPEN innovation website update**	**924 days**	**Wed 01/06/16**	**Fri 13/12/19**
98	✓	6 monthly update 1	3 days	Wed 01/06/16	Fri 03/06/16
99	✓	6 monthly update 2	3 days	Wed 14/12/16	Fri 16/12/16
100	✓	6 monthly update 3	3 days	Tue 30/05/17	Thu 01/06/17
101		6 monthly update 4	3 days	Thu 14/12/17	Mon 18/12/17
102		6 monthly update 5	3 days	Wed 30/05/18	Fri 01/06/18
103		6 monthly update 6	3 days	Wed 12/12/18	Fri 14/12/18
104		6 monthly update 7	3 days	Wed 29/05/19	Fri 31/05/19
105		6 monthly update 8	3 days	Wed 11/12/19	Fri 13/12/19
106		**Close-down report**	**82 days**	**Fri 01/11/19**	**Mon 24/02/20**
107		First draft preparation	60 days	Fri 01/11/19	Thu 23/01/20
108		Internal review	15 days	Fri 24/01/20	Thu 13/02/20
109		External consultation	15 days	Fri 24/01/20	Thu 13/02/20
110		Final submission	7 days	Fri 14/02/20	Mon 24/02/20
111		**SDRCs**	**0 days**	**Mon 24/02/20**	**Mon 24/02/20**
112		Effective Knowledge Dissemination	0 days	Mon 24/02/20	Mon 24/02/20



Project: ANGLE-DC Project Plan
Date: Fri 26/05/17

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Progress
Split	External Tasks	Inactive Summary	Manual Summary	Deadline
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

SECTION 5 PROGRESS AGAINST BUDGET

Below is a summary of the total project budget position from commencement to June 2017. The budget plan refers to the revised budget approved in the December 2015 project direction.

In line with the funding arrangements, SPM have contributed to costs incurred for a proportion of the expenditure in-line with the project direction. Costs for the NIC funded elements will be transferred from the bank account and a copy of the statement is included as a separate attachment (Appendix A).

Activity	Budget to Date (£k)	Actual to Date (£k)	Variance (£k)	Commentary
Labour	[redacted]	[redacted]	[redacted]	Less internal labour used than profiled to date.
Equipment	[redacted]	[redacted]	[redacted]	Payment profile now later than originally planned.
Contractors	[redacted]	[redacted]	[redacted]	Increased use of external labour and EMI consultancy.
IT	[redacted]	[redacted]	[redacted]	
Travel & Expenses	[redacted]	[redacted]	[redacted]	Project team trips to international suppliers haven't been required to date.
Contingency & Others	[redacted]	[redacted]	[redacted]	No use of contingency budget required to date.
Totals	[redacted]	[redacted]	[redacted]	

Several of the major costs for the project will occur later than originally profiled which is illustrated by the actual costs versus the budget to date.

In explanation of the budget figures:-

Labour – Some internal project resource has been supplemented with external support, therefore the cost of internal labour is reduced and contractor's costs are increased. Also the main construction works for the MVDC converter stations have not started yet.

Equipment – The outgoing payments for the project equipment to suppliers are different from the original anticipated payment profiles and therefore are less at this point in time.

Contractors – Increased use of external labour, the requirement to contract specialist consultants for the Network rail EMI issues and that the main construction works for the MVDC converter stations have not started, have caused the contractor costs to be higher than budgeted at this stage.

Travel & Expenses – the expected travel has been a lot less than budgeted for, also trips to international equipment suppliers has not been required so far (although some manufacture visits for Factory Acceptance Tests within Europe will be required).

Contingency – there has been no contingency budget used to date.

SECTION 6 BANK ACCOUNT

A copy of the bank statement, detailing the transactions of the project bank account since its creation, is attached to this report. The figures in the statement relate to the NIC funded costs only and not the total project costs. The total debit from the NIC bank account is lower than the NIC element of project costs until the date of the next costs reconciliation. Minor differences in the reconciliation between costs and funding being transferred from the bank account are due to timing of transactions.

SECTION 7 SDRC

This section describes the work to date associated with the project SDRCs. Over the reporting period, these SDRCs relate to development of the MVDC converter Technical Specification.

7.1.1 MVDC Technical Specification – SDRC 2

The project has delivered SDRC 2, in February 2017. The procurement of the MVDC converters provided an opportunity for the Technical Specification to be informed by the selected supplier. This Technical Specification contained: scope and objectives, electrical specifications, control strategy and site installation requirements.

The project is on track to deliver SDRC 3, by September 2017. Evidence of the commissioning of the HCCM will be provided in the form of a report published on the Angle-DC website.

Table 1. SDRC progress summary

SDRC	Status	Due Date	Comments
SDRC 1 - Publication of HCCM Technical Specification.	Complete	17/06/2016	Shared with all relevant stakeholders.
SDRC 2 - Publication of Converter Technical Specification.	Complete	24/02/2017	Procurement brought forward, with Technical Specification informed by design of selected supplier.
SDRC - 3 - Commissioning of HCCM system	On Track	15/09/2017	Expected to be completed ahead of schedule.
SDRC 4 – Factory Acceptance Test of MVDC Converters.	On Track	28/09/2018	Not started, but expected to be completed ahead of schedule.
SDRC - 5 Installation of MVDC Circuit/ Commissioning of Converters.	On Track	12/04/2019	Not started, but expected to be completed ahead of schedule.
SDRC 6 - Publication of Holistic Condition Monitoring data.	On Track	23/01/2020	Not started, but expected to be completed ahead of schedule.
SDRC 7 - Publication of operation performance of MVDC converters.	On Track	23/01/2020	Not started, but expected to be completed ahead of schedule.
SDRC 8 - Effective Knowledge Dissemination.	On Track	16/04/2020	Website updated. Three papers submitted to the CIRED 2017 conference. Webinar and Workshops have carried out to program.

SECTION 8 LEARNING OUTCOMES

Learning points are reviewed by the Angle-DC Project team at regular meetings to establish what was learned from the activities undertaken. The following learning outcomes, over the 3rd 6-month period of the project, are a detailed as follows:

Potential of EMI Safety Case: The CSM REA approach to safety is acceptable to the Network Rail E-SRP. Any converter equipment installed in proximity to Network Rail infrastructure should take into account: resonance affects and cross coupling between the AC network and DC circuit, stray currents caused by pole imbalances and lack of synchronisation (de-interlacing) between converter modules.

SECTION 9 INTELLECTUAL PROPERTY RIGHTS (IPR)

The project is not funding the development of any technology which should create foreground IPR. Cardiff University and SP Energy Networks have signed a collaboration agreement, accepting the NIC default IPR arrangements. We do not anticipate any further changes to this approach for any subsequent project partners.

SECTION 10 RISK MANAGEMENT

In order to ensure successful delivery of expected benefits and learning objectives of the ANGLE-DC Project, we proactively identify risks to the project and provide mitigation plans. The risk register is being updated regularly during the course of the project. All identified risks are list under four major risks areas (technical, procurement, operational and project management) and are listed in Table 2.

Four risks identified in the table have been updated with the current perception of the Project team. These are:

Risk 1.03 Harmonic Interference – In the past 6-months the project has engaged 3-suppliers deemed to be competent to contribute to the CSM-REA. The Project is currently a third of the way through the Phase I work. The E-SRP has approved the planned approach to the safety case following a productive HAZID workshop. However, the detailed work agreed between stakeholders is yet to take place, so there are still remaining uncertainties. The risk score remains 10/40.

Risks 2.07 Cost and Commissioning of Holistic Monitoring System – This risk is no longer relevant, since the equipment has been installed and is operational. This risk has been reduced to 0/40 and will be removed from future reports.

Table 2. Project risk register.

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
1. Technical risks					
1.01	Existing cables integrity with DC	Cables are unsuitable for DC operation at 27kV either due to age or type.	Project halted; delayed reinforcement and no demonstration of conversion to MVDC.	1. System operating DC voltage level kept at or below peak AC voltage level (27kV). 2. Conductor temperature limited to a maximum of 50°C for all cables. 3. Short time 27kV DC testing completed on the circuit with no problems.	5
1.02	Existing cable joints integrity with DC	Joints are unsuitable for DC operation at 27kV due to age or type.	Project halted; delayed reinforcement and no demonstration of conversion to MVDC.	1. System operating DC voltage level kept at or below peak AC voltage level (27kV). 2. Conductor temperature limited to a maximum of 50°C for all cables types. 3. Short time 27kV DC testing completed on the circuit with no problems	10
1.03	Harmonic interference	Superimposed high frequency interference on MVDC in existing cables couples with third party services.	Delay and additional cost to project in order to resolve problems for third parties.	1. Perform a study of VSC converter harmonics and determine likely interference 2. VSC converter filters to be designed to be adequate by converter supplier. 3. 2. CSM RA process to be carried out with Network Rail. 4. Further cable testing on harmonic impedance being carried out to understand harmonic attenuation.	10
1.04	Earthing with DC	High DC earth return currents.	Discontinued operation and additional cost to project to improve earthing arrangements.	1. VSC converter study required to determine the best converter arrangement for this application to reduce the level of earth return currents during normal and abnormal operation.	5
1.05	Existing cables integrity with DC	Cable fails on first energisation	Project halted; delayed reinforcement; additional costs to move MVDC converters for use elsewhere as converters or STATCOMS.	1. Short time 27kV DC testing completed on the circuit with no problems. 2. All cables to be fully discharged over an extended period (at least 24 hours) before DC energisation.	10

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
1. Technical risks					
1.06	Existing OHL integrity with DC	Suitability of existing OHL for DC operation	Flashovers across the insulators that provide structural support between the conductors and towers are likely to necessitate switching off the whole of the MVDC scheme for a period of time.	Perform study of OHL insulation requirements for designed DC voltage, visually inspect insulators on existing line and replace if necessary.	9
1.07	Practical realisation of capacity gain	Theoretical capacity gain with DC cannot be achieved.	Anticipated further deployments in the UK will be discouraged by less attractive business case.	Prior to decisions to proceed, pre-engineering studies will be carried out for the identified circuit to determine requirements for prudent operation and resulting anticipated capacity release.	2
1.08	Practical flexibility for replication of technology	Ambitious advancement of a combination of technologies from TRL in the region of 5 to TRL 7 cannot be achieved to facilitate project replications.	Anticipated further deployments in the UK will be discouraged by prohibitive cost to overcome unproven aspects.	Informal discussions have taken place with several potential vendors to understand the range of technology available for MVDC converters and constraints. A realistic functional specification has been developed in the proposal phase, and will be developed in the initial design phase to produce a detailed technical specification for the procurement process.	3

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
2.01	Few suppliers of MVDC equipment	Limited number of tender returns from vendors for procurement of MVDC converters.	Receipt of uncompetitive tenders that are not in line with principles of good value for money for customers; decision to halt innovation project.	This risk was not realised and has been closed.	0
2.02	Size of equipment	Insufficient available space and/or site access for installation of large plant items	Significant loss of investment in large equipment that cannot be installed; delays to reinforcement.	Preliminary assessments indicate that access is possible for plant and space is available at both sites. 1st version of GE design drawings indicate this the building dimensions are close to those required in the tender specification	4
2.03	Cost of installation of AC system is significantly higher than estimated	Prohibitive cost of cable installation for AC system. These costs are site-specific and heavily dependent on excavation costs (in this case directional drilling costs), with a high variance.	High cost of crucial mitigation measure delays entire innovative demonstration project.	1. Perform thorough pre-engineering studies before defining the detailed cable route. 2. Pause the project if there is no space available on the bridge. 3. Perform bridge survey with network rail.	10
2.04	Easements/ wayleaves	Inability to obtain a wayleave / easement for the parallel subsea AC standby circuit.	Lack of wayleave / easement for crucial mitigation measure delays entire innovative demonstration project.	Perform thorough pre-engineering studies before defining the detailed cable route and liaise closely with owners and planning authorities.	25
2.05	Cost of MVDC equipment	Prohibitive cost of MVDC equipment which is significantly higher than the estimated cost in proposal stage.	Project budget is not enough for delivery of the project objectives and project should be halted	This risk was not realised and has been closed.	0
2.06	Damaged equipment	Equipment arrive on site are damaged due to improper packaging and shipment	Significant effect on delivery time and project programme	1- Ensure proper packaging and shipment with supplier 2- include appropriate penalties in terms and conditions to protect the project against damage or late delivery of the products	8

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
2.07a	Delay in procurement of Holistic Monitoring System	Requested supplier information for tender is not available for SoW	Delay in ITT invitation to suppliers with knock on delay affecting commissioning of monitoring equipment and missing SDRC deadline	This risk was not realised and has been closed.	0
2.07b	Delay in commissioning of monitoring equipment	Holistic monitoring equipment is not in place before energisation of the MVDC link	The impact of conversion from AC to DC, the stress on the cables and possible damaged to the cable circuits cannot be monitored	This risk was not realised and has been closed.	0
2.08	Delay in delivery of converters	Delay in delivery of the MVDC equipment	The overall impact on timely delivery of the SDRCs and work in other work packages	1-Considering contingency time for production of the converters 2- Effective monitoring of the manufacturing process and define set dates for factory acceptance tests at time of contract 3- include appropriate penalties in terms and conditions to protect the project against damage or late delivery of the products	8
2.09	Most suitable MVDC supplier is not selected	Required Project/Supplier development work and MVDC - Link operation cannot be achieved	MVDC link is not fit for purpose, resulting in decision to halt innovation project and/or failure to meet several SDRC project outputs.	1) Invitation to tender sent out to all suppliers identified in 2 stages of PQQ. 2) 1st stage control strategy studies completed early to inform tender evaluation 3) Leading MVDC expert part of MVDC link tender evaluation panel.	6
2.10	MVDC supplier carries out the project as a one-off for SPEN	As a large customer, the selected MVDC link supplier modifies a HVDC converter design to curry favour with SPEN, but has little interest in entering the MVDC market.	BaU benefits of MVDC cannot be realised, Angle-DC has little effect on the emergence of the MVDC market	1) Pursue MVDC supplier's intent during MVDC evaluation 1-2-1s, with appropriate lines of questioning. 2) Perform market research into supplier's other DC - link projects 3) Effectively disseminate learning from project to lower the bar to MVDC market entry and keep supplier interest	8

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
3. Operational risks					
3.01	Landowners	Opposition to the conversion of the AC cable to operate with DC.	Discontinued operation and loss of significant investment.	Engage carefully and thoroughly with landowners to explain the change of technology and safe operation of cables under DC.	4
3.02	Reliability of the scheme	Inadequate reliability and availability of MVDC converters	Operation of the link is compromised.	1. Efforts will continue to be made to ensure that the specification requirements are reasonable and realistic for commercial offerings. 2. An AC link between Anglesey and Bangor will be commissioned.	6
3.03	Maintenance requirements	Complex system installed that is impossible to maintain in reasonable timescales.	Likely interruptions of supply to customers; and increased costs for additional resources in maintenance teams.	1. Seek to work with the manufacturers to understand maintenance requirements and the impact on the design or selection of components; as well as on-going training and development of staff. 2. Select converter with best maintenance approach.	4

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
4. Project Management Risks					
4.01	Higher costs	Cost of scheme higher than anticipated	Exceedance of project budget; and risk of halting the demonstration project.	1. FIDIC contract terms have been used, such that the contractor takes on some risk; 2. Commodity price to be hedged. 3. Contingency funding deemed to be reasonable and sufficient. 4. Tender MVDC converter costs are in-line with budget.	20
4.02	Experience and HSE	Staff lack of experience and knowledge of new equipment	Inefficient working and errors.	1. Support from competent resources in technical design details and project management. 2. Careful selection of the competent staff through interview process 3. Specialist tools and training required for maintenance activity. Procedures to be developed."	6
4.03	Resources	Sufficient resources are not available in SP Energy Networks to deliver the project	Delay in delivery of the project and impact on quality of deliverables	1. Effective engagement with Director level in SP Manweb to provide clear understanding about project size and resource required. 2. Use competent external resources where necessary.	4
5. Dissemination Risks					
5.01	Proliferation of learning not achieved	Project learning does not have a far reach in academic or public literature	Angle-DC project learning does not benefit wider industry and MVDC market	Appropriate selection process for academic partner, with a strong history of academic publishing in related field(s)	4

SECTION 11 OTHER

SECTION 12 ACCURACY ASSURANCE STATEMENT

The Project Manager and Director responsible for the 'NIC – Angle-DC Project' confirm they are satisfied that the processes and steps in place for the preparation of this Project Progress Report are sufficiently robust and that the information provided is accurate and complete.

Steps taken to ensure this are:-

- Regular update reports from each project team member for their area of responsibility.
- Evidence of work undertaken by the project team is verified by the section manager as part of their day-to-day activities. This includes;
  - Checking and agreeing project plans.
  - Holding regular team project meetings and setting/agreeing actions.
  - Conducting frequent one-to-one meeting and setting/agreeing actions.
  - Confirming project actions are completed.
  - Approving and signing off completed project documents.
  - Approving project expenditure.
- Weekly updates are received by each section manager of the progress of the work their department is undertaking.
- Director and Senior Management summary reports for the project progress are produced.

Signature (1): James Yu – Future Networks Manager

Signature (2): Colin Taylor – Engineering Services Director