NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

DECEMBER 2017

ANGLE-DC

Version:	1.0	
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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 4th 6-month period of the project, June to December 2017. It also details work due to be carried out in H1 2018.

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 four Steering Board meetings; in Q2 and Q4 2016 and 2017. Cardiff University have continued their academic work, submitting abstracts and papers to several international conferences.

Work Package 1 – Detailed Design

Findings from the Hazard Identification (HAZID) workshop have been used to develop a Hazard modelling process, involving GE Energy and 3-consultancies. The information requirements for the modelling studies are higher than anticipated, which has resulted in longer lead times. Progress is being made however by all task teams.

A Pre-Qualification Questionnaire and draft Scope of Works was released to network level control system suppliers in early October 2017. Feedback from suppliers has been used to inform the tender package, which will published by the end of December 2017. Technical evaluation and conclusion of the procurement process is expected to take place in Q1 2018.

Work Package 2 – MVDC Link

Detailed engineering design by GE Energy has continued, with GE's building specification requirements finalised in August 2017. SP Energy Networks has completed detailed building designs sufficient for inviting building suppliers to tender. The building tender process commenced in early November 2017. The requirements for the environmental conditions of the valve hall were more complicated than originally anticipated. To ensure the building design would comply with the specification, a building environment consultant company was employed to model and design air, heat, moisture, and dust control system, that will now be installed. The timeframe for the design of a thoroughly specified and evaluated converter station building has taken a lot longer than was planned for in the original project plan. This may impact on the overall delivery timescales of the project, however the project team are looking at ways this delay can be mitigated as the work progresses.

GE Energy has provided SP Energy Networks with datasheets on the converter main items, including the reactors, transformers, modules and the DC switchgear. These items are currently being assessed by SP Energy Networks experts/approvals to ensure they are compatible for use on the SP Energy Network system. GE estimates of sound power levels have been provided. These are being used with site location of the main plant items to carry out sound propagation studies at both sites. These studies will inform the levels of attention required by the building structure.

Work Package 3 – AC System

In October 2017, Network Rail granted a wayleave for the bridge section of the 33 kV circuit route. As of December 2017, the Iberdrola Engineering and Construction (IEC) team have almost completed the internal tender development work for the procurement of the back-up AC circuit and the tender will open to suppliers in Q1 2018. Dependencies for tender release include assessments of directional drilling sites; these have been identified and feasibility assessments are taking place. Most trial holes for the route have been dug, with only two outstanding near Llanfair PG substation. A number of landowner issues have prevented securing a definitive route for the new AC circuit, further discussions are taking place and other options are being considered, although these may impact delivery timescales.

Work Package 4 – Holistic Cable Condition Monitoring System

SP Energy Networks have submitted SDRC 3 which detailed evidence of the Holistic Cable Condition Monitoring system installation and data collected, showing the first set of AC Partial Discharge results.

Work Package 6 – Knowledge Dissemination

In June 2017, the Project submitted three conference papers to CIRED 2017. SP Energy Networks published a general overview paper and Cardiff University published two papers on the benefits and operational performance of MVDC converters in meshed Medium Voltage networks. All papers were presented in interactive tours at the event. In November 2017, Cardiff University submitted their first report to SP Energy Networks on their work to date. In December 2017, a webinar on the Holistic Cable Condition Monitoring system was hosted by the Project and a presentation on the project challenges was given at the Low Carbon Network Innovation 2017 conference.

1.3. Business Case

As of December 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. Early learning outcomes shall be published in H1 2018. These are detailed in Section 8 of this report:

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.

As the existing cables for use with DC cross Network Rail's bridge, we require their approval to operate the cables in DC mode. The risk associated with gaining Network Rail approval is still outstanding but has been reduced through engagement at the E-SRP meeting, the HAZID workshop and the significant amount of modelling/assessment work being undertaken.

SECTION 2 PROJECT MANAGER'S REPORT

The last six month 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 4th 6-month period of the project, progress has been made in six key areas, these are: (1) progress on the Common Safety Method Risk Evaluation and Assessment (CSM-REA), (2) a Pre-Qualification Questionnaire (PQQ) for the local and central network controller, (3) completion of the SDRC 3 report, (4) GE Energy's completion of the converter plant specifications, (5) completion of the building design for the converters and (6) development of tender packages for the back-up AC circuit.

2.1.1 Progress - Common Safety Method Risk Assessment

Detailed modelling of the bridge electromagnetic environment began in October 2017, focusing on the Hazards identified. Several delays have been encountered due to detailed contract negotiations between SPEN and a specialist consultancy and gaining approval from Network rail on the approach for a system resonance study; a pre-requisite for the bridge Electromagnetic Interference (EMI) assessment . In addition to GE Energy, three specialist consultancies have now begun work:

- TNEI – AC system harmonic resonance study;
- WSP – DC cable modelling up to the 200th harmonic; and
- Mott MacDonald – Bridge EMI modelling.

Due to a high level of information required by the three consultancies, the Phase I program of works has been extended to June 2018, when the CSM-REA safety justification report will be presented to the E-SRP. A decision on interim approval will then be given by Network Rail.

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 Network Level Controllers

In early October 2017, a Scope of Works (SoW) document, for the supply of a both the central and back-up controller, was issued to six suppliers under a PQQ. Distribution Active Network Management (ANM) is an emerging market, which has not matured sufficiently to judge whether suppliers can meet the requirements of the Project's control system. Supplier feedback, on the functional specification and information requirements, was used before full issue of the tender.

The tender will be released by the end of December 2017, with technical evaluation and selection due to take place during Q1 2018. The network controller (back-up and central) will be developed by one supplier, ready for installation and testing in Q1 2019.

2.1.3 Acoustic Survey

The main building design has been completed, which has allowed for sound insulating and reflection material to be incorporated into the building. GE Energy has released some conservative Sound Power values for their main plant items. These have been passed onto acoustic consultants who are undertaking noise propagation studies. The results, due in Q1 2018, will feed into the final building design before construction will begin.

2.2. Work Package 2 – Medium Voltage Direct Current (MVDC) Link

[redacted]

GE Energy is due to begin their procurement and manufacture of main plant items during Q1 & Q2 2018. In parallel, SP Energy Networks will conclude the procurement and detailed design of the building. During Q2 & Q3 of 2018, IEC shall carry out the construction of the MVDC converter buildings. This will be approximately 4-months after the original completion date.

2.3. Work Package 3 – AC System

In October 2017, Network Rail granted a wayleave for the bridge section of the 33 kV circuit route. As of December 2017, Iberdrola Engineering and Construction (IEC) have almost completed the internal tender development work for the procurement of the back-up AC circuit. Dependencies for tender release include assessment of sites requiring directional drilling. These have been identified and feasibility assessments are taking place. Most trial holes for the route have been dug, with only two outstanding near Llanfair PG substation.

In Q1 2018, the tender for the back-up AC circuit will open to suppliers. In the same quarter, a feasibility assessment to route the AC circuit along the A55 will be concluded. This will inform a decision on whether to continue to pursue a wayleave through a field adjacent to Llanfair PG substation.

2.4. Work Package 4 – Holistic Circuit Condition Monitoring System

Temporary GPRS modems were be installed in late June 2017 to allow online monitoring of Partial Discharge (PD) and real time alarms to be sent to an operations engineer. The modems also enable periodic downloading of PD data to an online server.

In Q1 2018, some reinstallation work of the Holistic Cable Condition Monitoring (HCCM) system will be carried out when the Overhead Lines (OHLs) are moved to make way for the

MVDC converter building at Llanfair PG. The HCCM server will also be moved into the converter substation building in Q3 2018 once the Bangor Converter substation is complete.

2.5. Work Package 5 – Data Analysis and Enhanced Learning

Collection of HCCM data began in February 2017 and will continue until Q3 2018, when the circuit is de-energised and the back-up AC circuit begins operation during the converter installation and commissioning. 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

In June 2017, the Project submitted three conference papers to CIRED 2017. SP Energy Networks published a general overview paper and Cardiff University published two papers on the benefits and operational performance of MVDC converters in meshed Medium Voltage networks. All papers were presented in interactive tours at the event. In November 2017, Cardiff University submitted their first report to SP Energy Networks on their work to date. In the same month, Cardiff University also presented a paper on MVDC dynamic control in distribution networks at the Conference on Energy Internet and Energy system Integration in Beijing. In December 2017, a webinar on the HCCM was hosted by the Project and a presentation on the Project challenges was given at LCNI 2017.

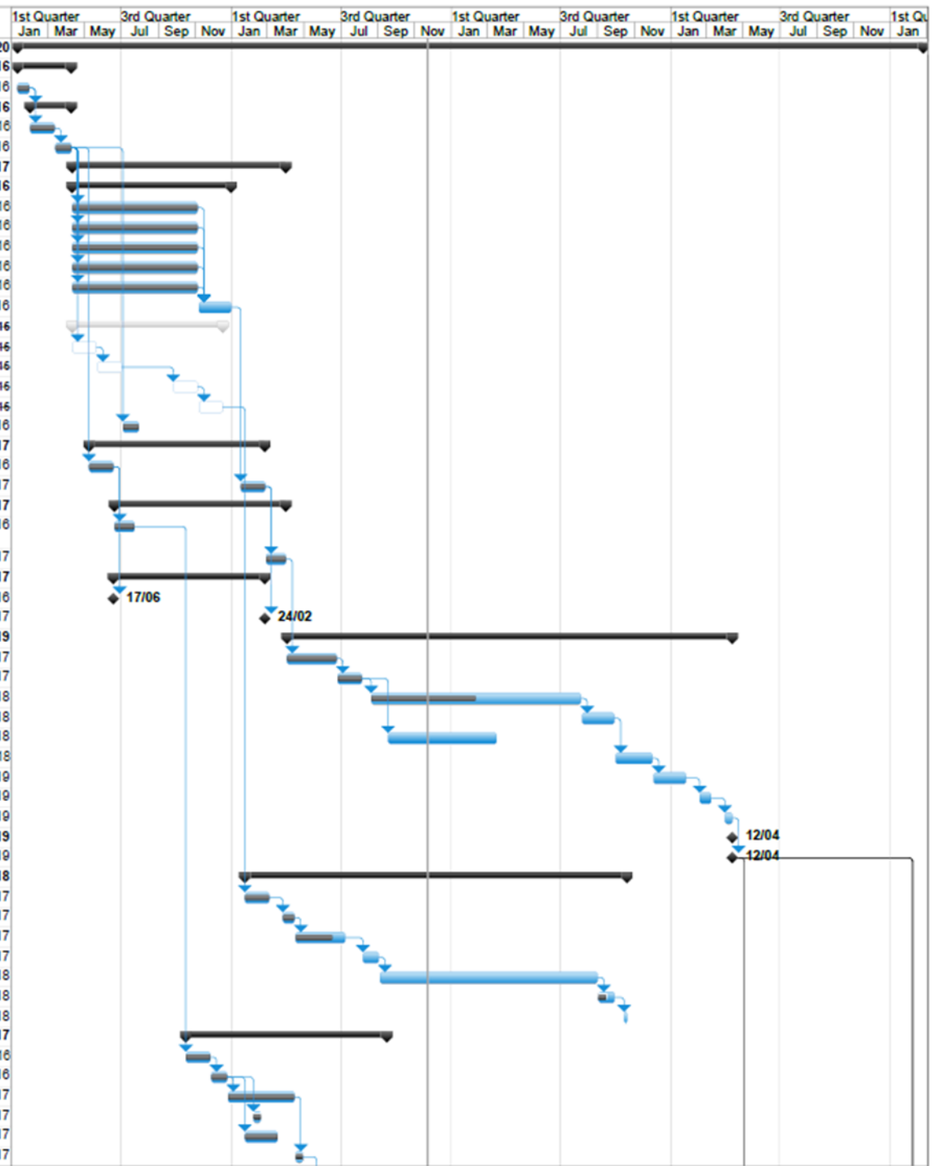
In February 2018, SP Energy Networks will be hosting a Real-Time Circuit Condition Monitoring workshop to industry experts at their training centre in Hoylake. SP Energy Networks have also issued a SoW to Cardiff University for a new task, focusing on harmonic transfer through MVDC converters of varying topologies. This was driven by the CSM REA requirements and will inform future projects by other DNOs. The work will be concluded in 2019.

SECTION 3 BUSINESS CASE UPDATE

To date there has been no change to the business case of the project. Cost estimates for the network level control system have been provided by suppliers, with several in line with expectations. 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	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



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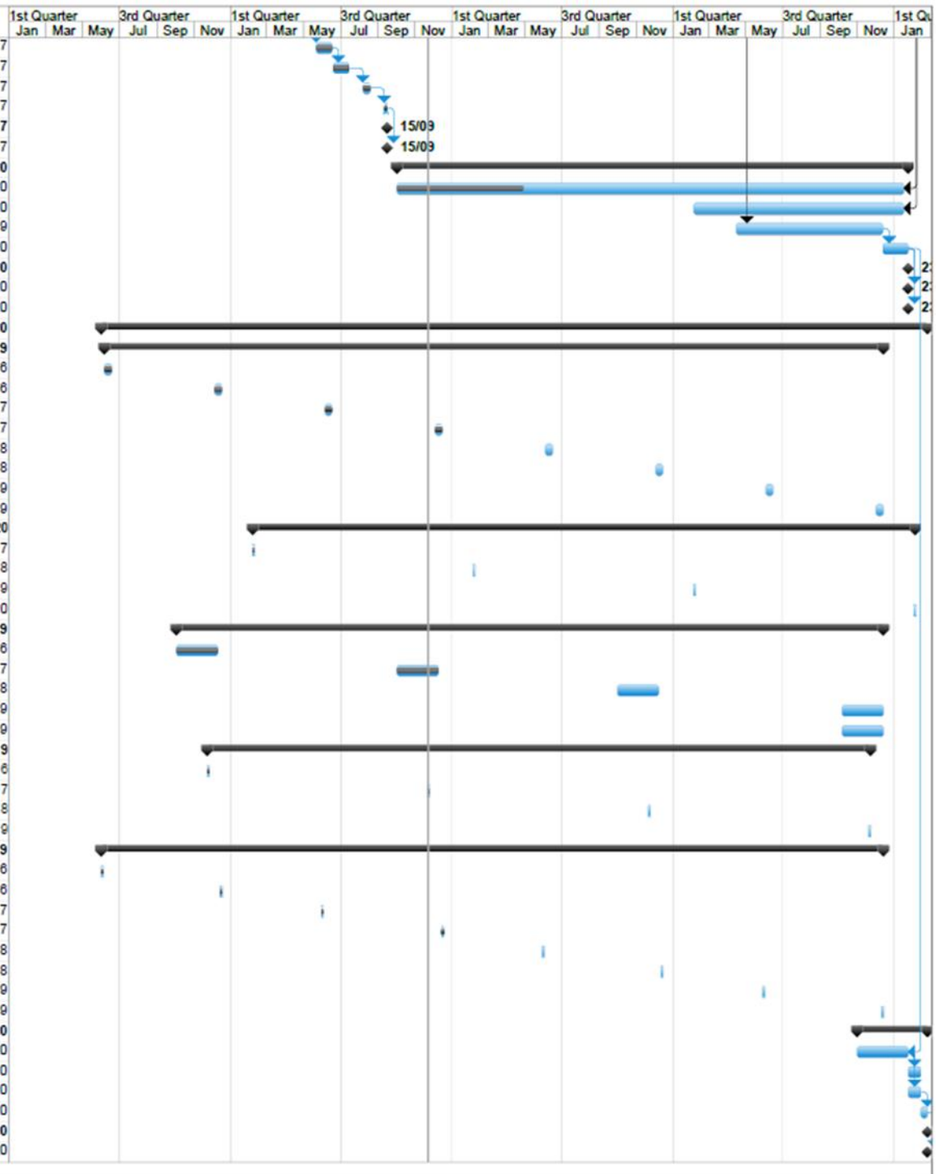
Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Progress
Deadline

ID	Task Name	Duration	Start	Finish
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
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 performance 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



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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 is slightly later than originally planned.
Contractors	[redacted]	[redacted]	[redacted]	Main building and cable laying contractor costs not yet incurred.
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 – As the main cable laying and converter station construction works have not started the labour costs are less that what was originally profiled.

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

Contractors – As the main cable laying and converter station construction works have not started the contractors costs are less that what was originally profiled.

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, this SDRC relates to installation and commissioning of the HCCM System.

7.1.1 – SDRC 3

The project has delivered SDRC 3, in November 2017. The installation and commissioning of the HCCM System was completed in Q1 2017 and data collection began at this time. A report describing the characteristics the Angle-DC HCCM system, including functionality, architecture and integration, was shared with stakeholders and uploaded to the website on the 15th of November 2017.

The project is on track to deliver SDRC 4 by the end of H2 2018, however SDRCs 5 and 7 are currently deemed at risk due to delays with the building design, procurement and construction. Quantification of this risk will be possible in Q1 2018 and will be reported.

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	Complete	15/11/2017	Shared with all relevant stakeholders and 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.	At Risk	12/04/2019	Not started, but this may not be met because of building construction. .
SDRC 6 - Publication of Holistic Condition Monitoring data.	On Track	23/01/2020	Not started, but expected to be completed on schedule.
SDRC 7 - Publication of operation performance of MVDC converters.	At Risk	23/01/2020	Not started, but this may not be met because of building construction delays.
SDRC 8 - Effective Knowledge Dissemination.	On Track	16/04/2020	Website updated with SDRC 3. Webinar has been 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 4th 6-month period of the project, are a detailed as follows:

EMI Safety Case Skill and Information Requirements: The CSM REA approach to risk management requires specialist skill sets which are not available within DNOs at present. Procuring these skill sets drives up the costs of delivery. Information requirements for the required studies are also high, which can have long lead times to extract information from various stakeholder organisations. The required information is also not always available.

Converter Station Design Interface: It has been very challenging to manage the interface with the converter station supplier for the strategy of SP Energy Networks providing the building accommodation for the equipment to be installed into. This has been because the supplier does not know at the outset of them being awarded the contract what equipment will be selected via a competitive tender process. This in turn creates dependency delays to the building design to accommodate the equipment whose specification isn't clearly known. The project team has therefore had to evolve a building design around emerging information of the equipment to be installed and this in turn has caused some re-work and delays. The reason that this strategy was chosen early on, was that if the tender was issued to include the building works, it was expected that each MVDC converter station equipment supplier's tender price could have varied dramatically due to different assumptions or designs in the building component. This approach would not have allowed precise control building design and construction and the clear evaluation of the converters offered between suppliers.

SECTION 9 INTELLECTUAL PROPERTY RIGHTS (IPR)

The project is not funding the development of any technology which should create foreground IPR. Mott MacDonald 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.

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

Risk 1.06 SPEN has carried out DC voltage testing on the double circuit OHL sections which showed very low levels of leakage current on the OHL insulators. The surge arrestor manufacturer has also been consulted and advised fitting new surge arrestors with a higher rating. SPEN will carry out this work to manage this risk. The risk score has been lowered to 6/40.

Risk 2.02 GE Energy has returned the specification sheets for the main plant items and has approved the IEC high level building design. This closes off the risk of the MVDC solution being too large for the land area available. This risk is now closed.

Risk 3.01 The risk of opposition to the conversion of the AC cable to operate with DC has now been closed following community engagement at several Energy Island events and discussions with landowners. Feedback has been positive overall, with no evidence of community concern.

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 on telecom and transport signalling after a study of installed services and harmonics to be generated. VSC converter filters/switching frequency to be designed to be adequate by converter supplier. 2. CSM RA process to be carried out with Network Rail. 3. Cable testing on harmonic impedance completed.	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

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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. SPEN will replace surge arrestors with sufficient DC rating.	6

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
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
2.06	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					
2.08	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					
3.02	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

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
3. Operational risks					
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

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