NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

DECEMBER 2016

ANGLE-DC

Version:	1.0	
Authored by:	Andrew Moon	– Engineering Consultant and Project Manager
	Kevin Smith	– Lead Engineer and Principal Project Manager
Approved by:	Colin Taylor	– Engineering Services Director

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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 2nd 6-month period of the project, June to December 2016. It also details work due to be carried out in H1 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 two Steering Board meetings in June and November 2016. Cardiff University have begun academic work in two key areas: released generator headroom and MVDC converter control schemes.

Work Package 1 – Detailed Design

Progress has been made on tendering process for both the Holistic Circuit Condition Monitoring system and the Medium Voltage Direct Current converters. Tender technical evaluations have been completed for both the converters and the monitoring system. The monitoring system supplier has been selected following procurement contract negotiations. The converter supplier selection is imminent, which will provide confirmation on the basic converter design.

An acoustic survey of both sites was carried out in November 2017, following a guidance meeting with the Environmental Health teams of both Anglesey and Gwynedd councils. The results of the acoustic survey will inform the design and layout of the converter stations.

A meeting with Network Rail, and a site survey of the Britannia Bridge, was carried out in early August, which provided the converter pole separation and proximity to the Network Rail signalling cable. Accredited suppliers have been approached with a Scope of Works to carry out a Common Safety Method Risk Assessment on Electromagnetic Interference. Following the supplier selection, the work is due to take place in H1 2017.

Following a preliminary set of studies on the MVDC converter control strategy by TNEI, a Scope of Works document has been produced containing a functional specification of the local controller, which will be housed in Bangor Grid sub-station. A tender process will be carried out in early 2017 to select an appropriate supplier. The supplier will design a local control system during the period of converter design in order to inform the overall design philosophy.

Work Package 2 – MVDC Link

The converter tender period concluded in July 2016. A period of bid evaluations has taken place, which has led to the MVDC converter suppliers taking part in a Best and Final Offer process and further evaluation of the revised bids.

Following the converter supplier selection, SPEN will draft the procurement contract with the selected supplier based on the FIDIC suite of contracts; this work is due to conclude in Q1 2017. Following this, converter detailed design will take place during H1 2017.

Work Package 3 – AC System

A two part route feasibility study is still underway. The first part is focused on drafting a route from Llanfair PG to Bangor substation. The Britannia Bridge owner, Network Rail, has indicated they can allow the back-up AC circuit to be laid within the existing cable trough. SPEN is supplying a schedule of information to support a proposal for territory clearance, which will result in a new wayleave for the cable. Off the bridge, verbal agreement has been reached for cable installation around Bangor. On Anglesey, work is still underway with landowners for consent.

During H2 2017, gaining consents for back-up AC route should be concluded. Iberdrola Engineering and Construction will also begin their program of works, which will include conducting tenders for the procurement of the back AC cable and protection equipment.

Work Package 4 – Holistic Cable Condition Monitoring System

The provision of the Holistic Monitoring System contract has been awarded to HVPD Ltd. The substation ducts and multicore cables are currently being installed, in preparation for the monitoring system equipment installation in Q1 2017. The monitoring system transducers are scheduled to be installed during the opportunity for a limited outage of the Llanfair – Bangor Grid 33kV cable in December 2016.

Work Package 6 – Knowledge Dissemination

During Oct 2016, the Angle-DC project was present at the Low Carbon and Network Innovation 2016 conference. A bi-lingual brochure outlining key aspects of the project had been produced for visitors and the project management team were on hand to talk about the project. Future brochures will be produced, with information updates and shared at key dissemination events.

Two papers have been submitted and accepted by the IET 13th international conference on AC and DC Power Transmission. One paper is on a general project overview and other on the MVDC link operational envelope study. The two papers are due to be presented at the conference in February 2017. During H1 2017, Cardiff University will be submitting two conference papers to CIRED 2017.

1.3. Business Case

As of December 2016, there has been no change to the business case of the project. The cost for both the monitoring system and converter stations are now known. Over the next 6-months, the results from the Common Safety Method Risk Assessment on Electromagnetic

Interference 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:

MVDC Converter Development: We have learned of the various basic designs approaches a possible MVDC converter market can offer. Each design presented by suppliers can fulfil almost all requirements of the MVDC converter functional specification developed at the project bid stage. The prices offered by manufacturers have been in the bracket that was expected.

Potential for EMI: The project offers a key learning outcome for other DNOs in the form of gaining approval from Network Rail and the Office of Rail Regulation for the conversion from AC to DC near railway infrastructure. A Common Safety Method Risk Assessment is to be produced which will help other MVDC projects where they operate near Network Rail assets.

Liaison with Similar Projects: The Angle-DC project management team met with two other NIC projects during H2 2016; SSEPD's Multi Terminal Test Environment project and WPD's Network Equilibrium. Project learning to date was shared at the meetings and future collaboration events are to be held to enhance research efforts across all the projects.

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.

A key risk is the exclusion of the most appropriate MVDC converter supplier, has largely been mitigated through the conduct of a successful tender exercise. All suppliers approached responded to the request for tenders. Another key risk is unsuccessfully stimulating suppliers to develop MVDC converter market solutions, this is looking less likely following engagement with all suppliers in one to one meetings.

The risk associated with gaining Network Rail approval has been reduced through engagement, though 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 2nd 6-month period of the project, progress has been made in five key areas, these are: development of the tender documentation for a Common Safety Method Risk Assessment (CSM RA) and the supply of a local controller, further development of the technical specification for Medium Voltage Direct Current (MVDC) converters, an acoustic survey at both Llanfair and Bangor Grid substations and further work on harmonic loci.

2.1.1 Tender Development - Common Safety Method Risk Assessment

Following discussions during a site survey of Britannia Bridge, a process has been identified that will provide the best chance of approval for the conversion of the cable from AC to DC operation. The process is a Common Safety Method Risk Assessment (CSM RA) which will form the supporting evidence to justify Electromagnetic Compatibility (EMC) with Network Rail infrastructure. SP Energy Networks (SPEN) is tendering with two types of supplier for this work area; a CSM Risk Assessor and a CSM Assessment Body (AB). The AB will assess the CSM RA and provide a Safety Assessment Report which will be reviewed by the Network Rail Electrification Systems Review Panel for compliance before the final report is sent to the Office of Rail Regulation. The CSM RA will be carried out in two phases.

Phase I of the CSM RA will take place during H1 2017, which will cover hazard identification and safety requirement identification for the converter EMI in all modes of operation and failure states. The CSM suppliers will be selected by Q1 2017. 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 Tender Development – Local Control

Building on the systems studies work carried out in May 2016, a local controller functional specification has been developed. The local controller fits into the overall control strategy as follows:

1) MVDC Voltage Source Converter (VSC) Controller: voltage and power control of the MVDC converters
2) Automated Constraint Management (ACM): Management of Bangor Grid Transformer (GT) outage
3) Local Control Response: control of the MVDC link within a derived operational envelope
4) Central Control Scheme: Further optimisation of the set-point from wider SCADA data

A Scope of Works (SoWs) document, for the supply of a local controller, has been developed by SPEN, which is being issued to suppliers. It was decided to include elements of the ACM scheme in the SoW for the local controller supplier. These elements include establishing the required MVDC converter real power ramp rates in the case of a fault at the Bangor GT, which will involve some transient studies.

Technical evaluation and supplier selection will take place during Q1 2017. 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 converter functional specification, developed as part of the submission, has been further developed using learning from the tender process, supplier one to one meetings and the tender submissions. The Technical Specification for the MVDC converters will be published on the Angle-DC website during February 2017.

2.1.4 Acoustic Survey

In September 2016, SPEN completed a SoW and tender exercise for the provision of an acoustic survey at both Llanfair PG and Bangor Grid substations. The purpose of the Survey is to establish the maximum allowable noise emissions of the MVDC converter stations at both sites without causing a nuisance to local residents. SPEN and the acoustic survey supplier liaised with the Environmental Health teams of both Anglesey and Gwynedd councils to establish a best practice approach to conducting the survey in Q4 2016. Recording of the existing noise levels at both sites took place over a period of 4-weeks starting in November 2016.

A noise propagation assessment and analysis will be included in report to support the permitted development status of the converter stations. The report, to be produced in January 2017, will also inform the physical layout and building specification for the MVDC converters, which will be developed in H1 2017.

2.1.5 Harmonic Loci Study

Work on harmonic analysis was carried out in late June 2016, which consisted of deriving harmonic impedance loci at identified critical bus bars for each operational scenario assessed in the local controller operational envelope study. This information will be issued to the selected MVDC converter supplier, to aid the design process for harmonic performance on the AC side of the network.

In December 2016, the background harmonics (up to the 100^{th}) are being recorded before and during an outage of the Llanfair to Bangor Grid 33 kV circuit. This monitoring is to capture the effect of separating the two networks and assessing the impact on background harmonics; a requirement since the MVDC link will sit between the two separated networks and must satisfy harmonic limits at each end.

2.2. Work Package 2 – MVDC Link

A 5-month bid evaluation has taken place, which has involved MVDC converter suppliers taking part in a Best and Final Offer process following the technical evaluation of the bids. Two suppliers have offered prices for the MVDC converters that are in line with the project converter budget. Converter suppliers have confirmed MVDC manufacturing and deployment can be achieved within 23-months. Most supplier solutions were based on scaled down transmission designs, with one supplier opting for a modified MV converter used in traction substations. All supplier solutions met most of the requirements contained within the functional specification.

Following supplier selection, SPEN will draft the procurement contract, with the selected supplier, based on the FIDIC suite of contracts. This work has already begun and is due to conclude in Q1 2017. Following signing, the converter detailed design phase will take place during H1 2017 at which time findings from the acoustic surveyor, harmonic loci studies and EMI CSM RA will inform the converter design.

2.3. Work Package 3 – AC System

A two part route feasibility study is still underway. The first part is focused on drafting a route from Llanfair PG to Bangor substation. The Britannia Bridge owner, Network Rail, has indicated they can allow the back-up AC circuit to be laid within the existing cable trough. SPEN is supplying a schedule of information to support a proposal for territory clearance which will result in a new wayleave for the cable. Off the bridge, agreement has been reached for cable installation around Bangor. On Anglesey, work is still underway approaching landowners for consent.

During H2 2017, gaining consents for back-up AC route should be concluded. Iberdrola Engineering and Construction will also begin their program of works, which will include conducting tenders for the procurement of the back AC cable and protection equipment. In Q1 2017, SPEN will dig trial holes along the proposed route in order to establish the location of existing utilities.

2.4. Work Package 4 – Holistic Circuit Condition Monitoring System

The provision of the Holistic Monitoring System contract has been awarded to HVPD Ltd. The substation ducts and multicore cables are currently being installed, in preparation for the monitoring system equipment installation in Q1 2017. The monitoring system transducers are scheduled to be installed during the opportunity for a limited outage of the Llanfair – Bangor Grid 33kV cable in December 2016.

Installation of the equipment and commissioning tests are on track to be concluded by June 2017. This will allow for 17-months of AC online Partial Discharge monitoring before the converter commissioning stage begins.

2.5. Work Package 5 – Data Analysis and Enhanced Learning

Collection of HCCM data will from 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 is set to begin in H2 2017.

2.6. Work Package 6 – Knowledge Dissemination

During Oct 2016, the Angle-DC project was present at the Low Carbon and Network Innovation 2016 conference. A brochure, outlining key aspects of the project, was available from the SPEN stand. This brochure will be updated and shared at key future stakeholder dissemination events.

Two papers have been submitted and accepted by the IET 13th international conference on AC and DC Power Transmission. One paper is on a general project overview and other on the MVDC link operational envelope study. The two papers are due to be presented at the conference, in February 2017, by James Yu (SPEN) and Russell Bryans (TNEI).

During H1 2017, Cardiff University should submit two conference papers to CIRED 2017 based on their work. The first paper is on the Distributed Generation (DG) headroom increase due to the MVDC link and possible ways to convey the information to community groups and other stakeholders. The 2nd paper is on various control strategies of VSCs. Cardiff University should present their work at the LCNI 2017 conference in June.

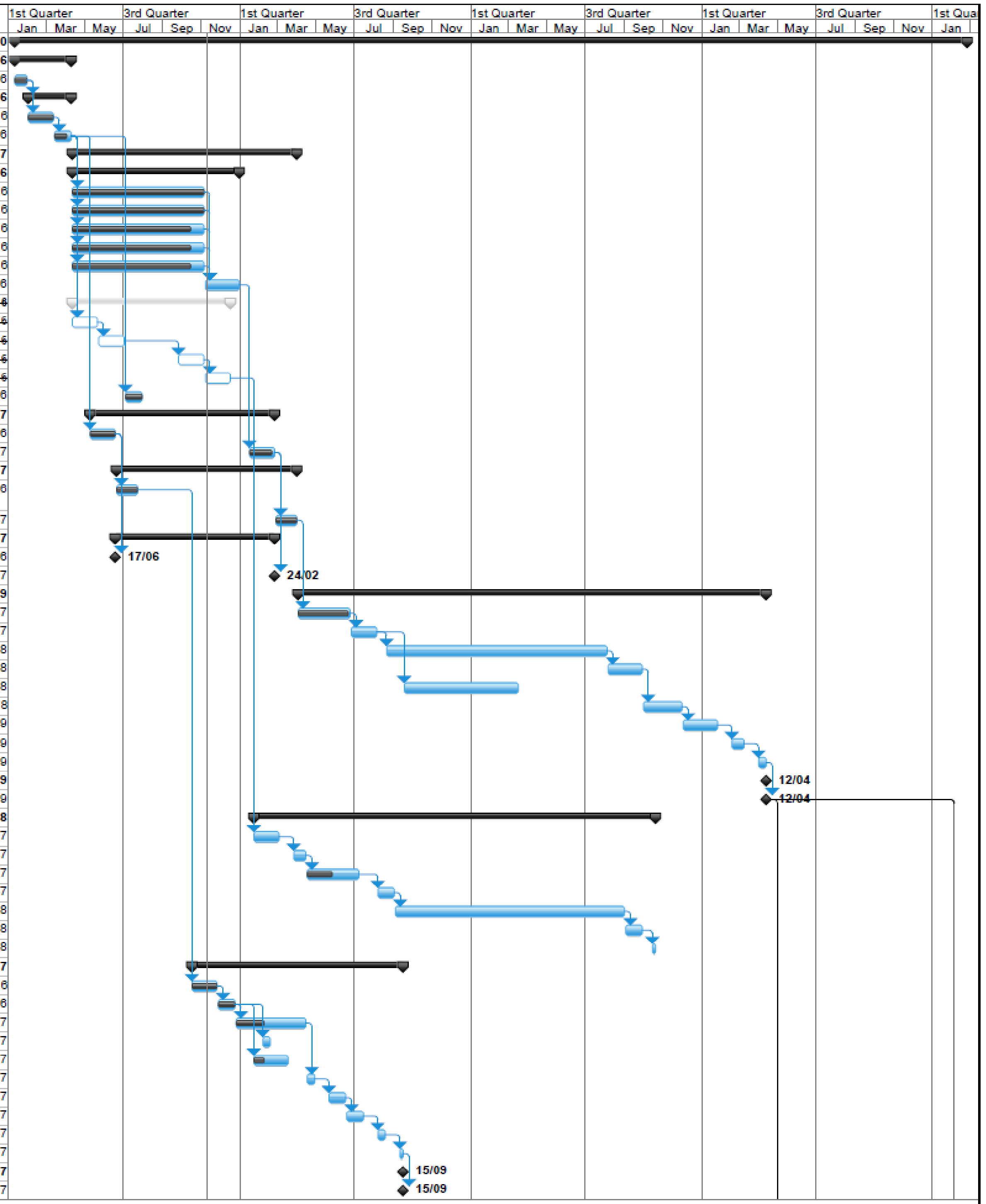
A webinar on MVDC technology and supplier engagement, followed by a workshop on MVDC converter technical design will take place in Q1 2017. The webinar timing is to be arranged to allow for the selection of the MVDC converter supplier.

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 RA should provide some indication of any required changes.

SECTION 4 PROGRESS AGAINST PLAN

ID	Indicators	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
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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
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 2016. 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]	Main construction works not started yet.
Equipment	[redacted]	[redacted]	[redacted]	No initial payment made to MVDC supplier yet.
Contractors	[redacted]	[redacted]	[redacted]	Main construction works not started yet.
IT	[redacted]	[redacted]	[redacted]	N/A
Travel & Expenses	[redacted]	[redacted]	[redacted]	Necessary travel lower than plan.
Contingency & Others	[redacted]	[redacted]	[redacted]	No contingency required to date.
Totals	[redacted]	[redacted]	[redacted]	

Several of the major costs for the project have yet to be incurred which is illustrated by the actual costs versus the budget to date. In particular;

Labour – the main construction works for the MVDC converter stations have not started. The converter station design/layout specifications are required from the supplier. These will not be available until the supplier contract is awarded.

Equipment – the Holistic Cable Circuit Monitoring system installation has only recently started and therefore final payments have not yet been incurred.

Contractors – similar to the labour costs, the main construction works for the MVDC converter stations have not started.

Travel & Expenses – the budgeted travel to international equipment suppliers has not been incurred by the project to date.

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 is on track to deliver SDRC 2, due in February 2017. The procurement of the MVDC converters will provide an opportunity for the Technical Specification to be informed by the selected supplier. This Technical Specification will contain: scope and objectives, electrical specifications, control strategy and site installation requirements. To enable an accurate MVDC converter design, suppliers have been provided with normal and fault conditions, harmonic background and network data in the invitation to tender documentation.

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.	On Track	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	Not started, but 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. Two papers submitted to IET ACDC conference.

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 2nd 6-month period of the project, are a detailed as follows:

MVDC Converter Development: We have learned the various basic designs approaches a possible MVDC converter market can offer. Each design presented by suppliers can fulfil almost all requirements of the MVDC converter functional specification developed in the project bid stage. Two main design choices have been taken by suppliers: downsizing of MVDC converters from bespoke HV transmission technologies and modified MV traction converters. The prices offered by half of the manufacturers are within the maximum allowable budget.

Potential of EMI Safety Case: The project offers a key learning outcome in the form of gaining approval from Network Rail and the Office of Rail Regulation for the conversion from AC to DC on the Britannia Bridge. This learning should further reduce the barrier for adoption of MVDC converters for other UK DNOs. Should approval be granted, the circuit conversion will provide a reference case for future CSM RAs, which will de-risk other follow on DC projects.

Liaison with Similar Projects: The Angle-DC project management team met with two other NIC projects during H2 2016; SSEPD's Multi Terminal Test Environment project and WPD's Network Equilibrium. Project learning to date was shared at the meetings and future collaboration events were arranged to enhance research efforts across the projects. In December 2016, the Angle-DC team also met with Flexible and Future Power Links for Smart Grids project, which has similar objectives to the Angle-DC project, albeit on a smaller scale. Potential areas of mutual benefit were identified and further collaboration between the projects is expected.

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 – Over the past 6-months a greater understanding of how interference, caused harmonic currents, can affect the performance of existing track side equipment on the Britannia Bridge. Through engagement with network rail, a route to approval has been identified which lowers the risk from one perspective. However, gaining approval of a new and novel system through the CSM is no trivial task and represents a piece of work with remaining uncertainties. This has increased the risk score to 10/40.

Risk 2.01 Few suppliers of MVDC equipment – This risk is no longer relevant, since all MVDC converter tender submissions were technically compliant. This risk has been reduced to 0/40 and will be removed from future reports.

Risk 2.05 Cost of MVDC equipment – This risk has been mitigated through a successful tender exercise. Turnkey costs are in-line with the submission budget for the majority of supplier tenders. Some risk is still present if unforeseen design changes are required. This risk has been reduced to 5/40.

Risk 2.07a Delay in procurement of HCCM system - This risk is no longer relevant, since the HVPD have been appointed ahead of schedule. 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

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

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

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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.	Tender process completed, risk not realised.	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.	5
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

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
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	1. Develop an optimum design for MVDC equipment and ensure unnecessary and expensive specifications will not be part of final specifications 2. Carry out competitive tendering process to ensure the best value for money	5
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
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	Procurement complete.	0

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
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	1- Commissioning of the holistic monitoring system is planned to take place before commissioning of the MVDC link (at least 6 month earlier than originally planned) 2- Early IT engagement to ensure incorporating monitoring system in SP Energy Networks infrastructure comply with IT security requirements	3
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

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
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
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 should be used, such that the contractor takes on the 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