NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

JUNE 2020

ANGLE-DC

Version:	1.0	
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SECTION 1 EXECUTIVE SUMMARY

1.1. Summary

The key achievements for the reporting period include: 1) The completion of civil construction activities of the Bangor and Llanfair buildings, 2) the installation and commissioning of the AC backup circuit 3) the development progress of the network level control system and 4) the installation of Medium Voltage Direct Current substation equipment.

Despite the progress that has been made, several key risks remain outstanding. These include: the completion of the network control system, harmonic interference on the Britannia Bridge, delivery under the COVID 19 crisis and higher costs for the completion of the Project. These risks are discussed in detail in Section 10 of this report.

1.2. Project Background

The Angle-DC project is funded through Ofgem's Network Innovation Competition. Angle-DC commenced in January 2016 and was originally planned to be implemented within 5-years. 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 12-month period of the project, between June 2019 and June 2020. It also sets out work due to be carried out between June and December 2020.

1.3. Project Progress Highlights

The MVDC Link is now envisaged to be hot commissioned in August to October 2020, given the latest project developments. Significant and commendable efforts have been put in by the project team, SPEN senior management and suppliers, to rectify and minimise the delays associated with the COVID 19 crisis.

This report will present a best view from the Project Manager on behalf of the project delivery team, along with the key risks encountered, addressed and those that can potentially arise.

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 six Steering Board meetings, two each year from June 2016 until June 2018 and one in 2019. The next should take place in Q4 2020.

Work Package 1 – Detailed Design

Detailed modelling of the bridge electromagnetic environment has progressed, with a scope of works and methodology agreed between SPEN, Network Rail and the MVDC supplier. [redacted]

In the interim between commissioning and full operation, the Common Safety Method -Risk Evaluation and Assessment safety justification report should be presented to the Electrification – System Review Panel.

The network level control system work program has been extended from Q1 2020 to Sept 2020. This is partly due to long equipment lead times caused by factory shutdown under Coronas Virus lockdown arrangements.

Work Package 2 – MVDC Link

The MVDC converter transformers are now installed in their final locations at Llanfair PG and Bangor Grid substations. These units have undergone a final condition assessment ahead of commissioning. The commissioning for these units will take place in June 2020.

All converter modules have been installed with the MVDC converter control cabinets and DC reactors. The control cabling installation took place in April and May 2020.

The DC switchgear procurement and design process resumed in September 2019 . The final specification raised some compliance issues, which required some small modifications at the factory in Germany. The DC switchgear was delivered to site in May 2020 and is currently being erected.

The buildings construction work began in February 2019 and was mainly completed in January 2020. Equipment installation commenced in January and is currently being completed. Cold commissioning activity will start in June 2020 and shall conclude in early July 2020. Operational commissioning shall take place between August and October 2020.

Work Package 3 – AC System

The safety case for directional drill was accepted by Network Rail, allowing works to be completed in November 2019. This work took place under challenging conditions due to unprecedented levels of heavy rainfall in Q4 2019. The easements and wayleaves for the AC cable have now been finalised. The cable installation concluded in December 2019 and the cable was commissioned in March 2020. The circuit was energised and made operational in May 2020. After a soak-in period, this new circuit will now facilitate the transfer of the existing circuit cables to be the DC Link between the converter stations.

Work Package 4 – Holistic Cable Condition Monitoring System

No Partial Discharge monitoring has taken place during the reporting period. The system has been temporally removed from service while the construction and circuit reconfiguration takes palce.

In August 2020, the Holistic Cable Condition Monitoring System shall be reinstalled following the installation of the DC switchgear, which will house the monitoring transducers. This will allow continuous online partial discharge and power quality monitoring during the commissioning and operational phases of the MVDC converter.

Work Package 6 – Knowledge Dissemination

The Project presented at LCNI 2019, but no academic activity took place during the last 12 months.

Over the next 6 – months, the Project shall hold a webinar and workshop on MVDC operational performance and publish several reports, policy documents and papers on the operational learning. Cardiff University shall develop a network heat map showing the comparative benefits.

1.4. Business Case

The commercial contract completion of the MVDC buildings and MVDC system are outstanding and therefore there is still an opportunity for budget risks to materialise. Should these risks not occur, the business case remains unchanged.

1.5. Learning Outcomes

Learning points are reviewed by the Angle-DC Project team at regular meetings to establish what was learned from the activities undertaken. These are detailed in 0 of this report.

1.6. Key Risks

At this stage, some 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 12-months.

The key risks in this reporting period are

- [redacted].
- The completion of the network level control system due to supply and development lead times caused by the COVID 19 crisis.

SECTION 2 PROJECT MANAGER'S REPORT

The last twelve-month period has seen progress in several 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.

Between June 2019 and June 2020 project progress has been made in four key areas: 1) The completion of civil construction activities at Bangor and Llanfair substations, 2) the completion and commissioning of the AC backup circuit 3) and the development progress of the network level control system and 4) the installation of the MVDC substation equipment.

2.1. Work Package 1 – Detailed Design

2.1.1 Common Safety Method Risk Assessment

An AC/DC interaction study provides information on which AC network and converter operation states give rise to control system instabilities and effects on the DC cable current. Following a commercial agreement, the MVDC supplier, SP Energy Networks and Network Rail held a meeting in September 2019 to define the Scope of Works. Following the meeting, Network rail approved the Scope of Works and this was issued to MVDC Supplier in December 2019.

[redacted] To reduce the program timescales, the commissioning plan will provide demonstration of compliance with safety requirements, through testing and validation of EMI models, immediately after the report has been produced. Testing and validation will be as part of the converter system commissioning, programmed to take place between August and Oct 2020.

2.1.2 Network Level Controllers

Nortech Energy management are continuing to work with SP Energy Networks in the development phase of the work. Due to impact of the COVID lockdown, the development, design and installation work will take 15 months to complete, with commissioning from September 2019 to October 2020.

The control system is a critical component to the operation of the MVDC link and therefore still represents a risk to delivery of the MVDC operational commissioning. This risk is discussed in Section 10.

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

SP Energy Networks have taken delivery of all the main plant items. These items are the converter modules, transformer, DC switchgear and line reactors. Delivery and installation details are described below.

2.2.1 Converter Modules

The converter modules were transported their final locations in mid-March at Llanfair PG and Bangor Grid substations. The installation was completed by the end March. Following this, connections of LV power cabling, earthing and control cabling took place in April. The DC busbars were fitted to the modules in early May and the AC cabling was connected between the AC busbars to main power transformers in early June 2020.

In June, the modules will undergo hardware commissioning and cold commissioning will conclude by the end of July 2020.

2.2.2 Transformers

Following long term storage at a Grid Substation, SP Energy Networks lifted the four transformers for onward transport in early April. All four units were transported to their final locations and have passed a final condition assessment ahead of commissioning.

The AC terminations are to be made-off ahead of hardware commissioning and cold commissioning in July 2020.

2.2.3 DC Switchgear

The approvals process concluded in March 2020, with delivery taking place in late May 2020 and installation taking place in June 2020.

Once installed, the double circuit will be decommissioned as an AC asset. In July the DC cable will jointed between the switch gear and double circuit at both substations. Hardware commissioning and cold commissioning will also take place in July 2020.

The DC switchgear is designed and manufactured as a 36kVAC AIS unit, with only two (L1 & L3) of the normal three phases installed. The disconnector will only be used as off-line operation as it cannot break DC load.

2.2.4 DC Line Reactors

The reactors were shipped and installed at the same time as the modules. DC switchgear cable termination were made in early June 2020. Hardware commissioning and cold commissioning will take place in July 2020.

MVDC System Tests and Commissioning Plan

In H2 2019, the commission plan and procedures were reviewed, and the final file structure and contents were finalised. SP Energy Networks commissioning engineers reviewed the hardware commissioning plan and met the GE commissioning team at site in early June to walk through the cold commissioning procedures. The hardware commissioning sheets will be completed in July and fed into the SDRC 5 report.

2.3. MVDC Converter Buildings

The buildings works were ready for equipment occupancy in January 2020, with Llanfair building construction being completed at the same time as the Bangor. Both sites continued with outdoor civil completion works up to June 2020.

2.4. Work Package 3 – AC System

SP Energy Networks completed the Horizontal Directional Drill (HDD) works following a short delay due to very heavy rainfall in H2 2019. The post drill ground settlement monitoring was concluded 2 weeks later. Network Rail signed the safety case off in December 2019.

SPEN completed the duct and cable lay where the cable crosses the A55 Bridge in December 2019. Following the completion of the civils works, the cable was jointed, and pressure tested in January 2020. The circuit was energised in mid-May 2020 following disconnector and switchgear Balance of Plant works. The circuit will be run until the MVDC circuit commissioning in H2 2020.

2.5. Work Package 4 and 5 – Holistic Circuit Condition Monitoring System and Data Analysis

No Partial Discharge monitoring has taken place during the reporting period. The system has been removed from the network until the building has been completed.

In August 2020, the partial discharge monitoring equipment will be re-commissioned within the converter building following equipment installation by the MVDC supplier. The transducers will be housed within the DC switchgear. The partial discharge monitoring equipment will record power quality emissions for the stations and real-time DC partial discharge on the DC Link cables. This will enable the trial to understand the partial discharge effects under DC operation.

2.6. Work Package 6 – Knowledge Dissemination

The Project presented at LCNI 2019, but no academic activity took place due to the 15-month project extension.

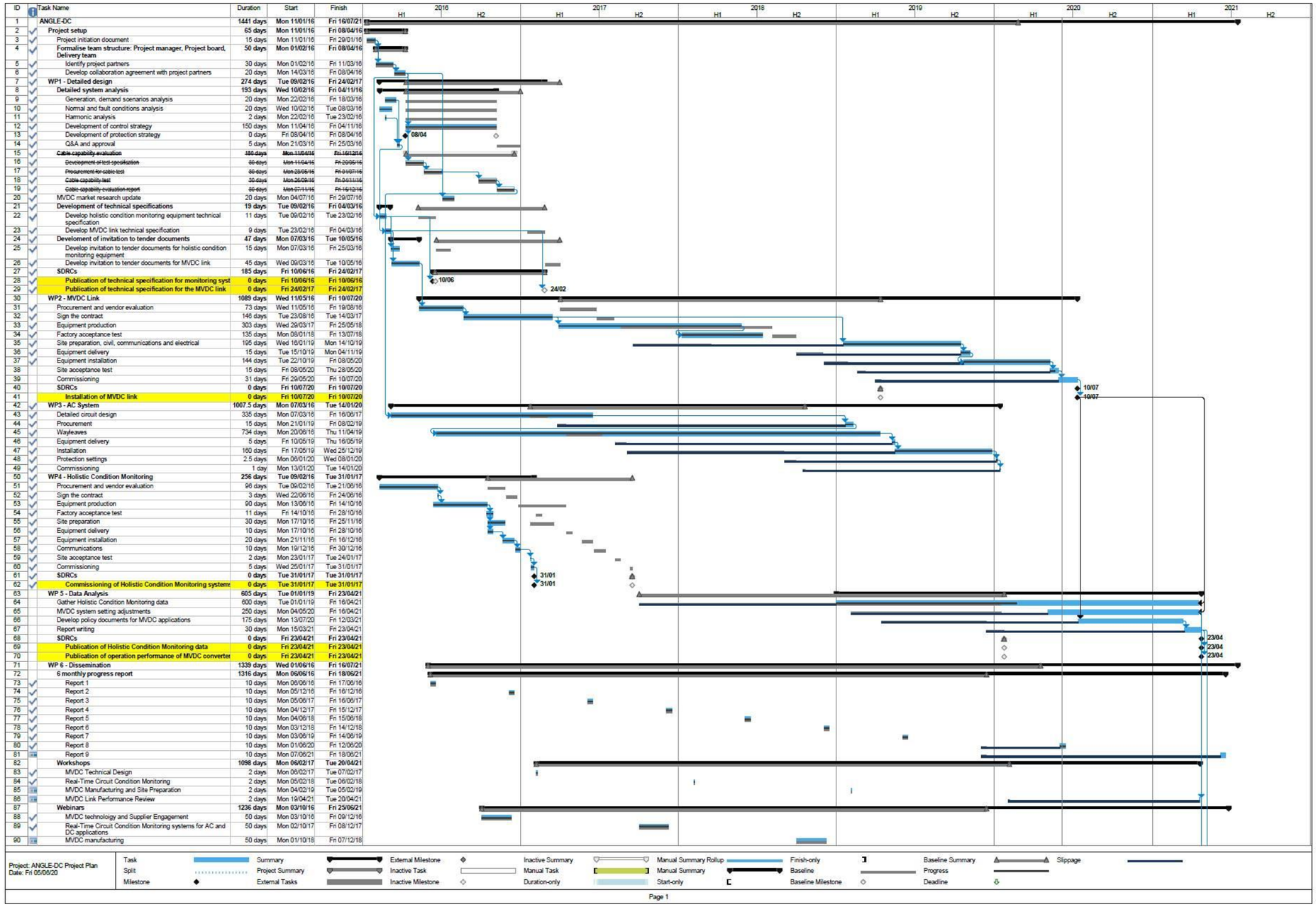
Over the next 12 – months, the Project shall hold a webinar and workshop on .MVDC operational performance and publish several reports, policy documents and papers on the operational learning. Cardiff University shall develop a heat map, which will communicate the benefits of the MVDC link through a network heat map. .

SECTION 3 BUSINESS CASE UPDATE

To date, there has been a revision of the business case due to the high cost of the MVDC converter buildings. The building cost risk has been contained but has impacted the project contingency. The business case is under continual review, but the project as a whole is currently within budget.

[redacted]

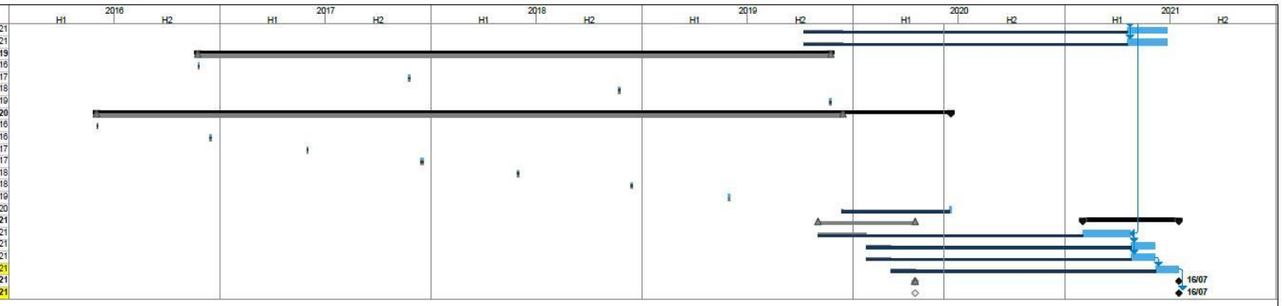
SECTION 4 PROGRESS AGAINST PLAN



ID	Task Name	Duration	Start	Finish
1	**ANGLE-DC**	**1441 days**	**Mon 11/01/16**	**Fri 16/07/21**
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**	**274 days**	**Tue 09/02/16**	**Fri 24/02/17**
8	**Detailed system analysis**	**193 days**	**Wed 10/02/16**	**Fri 04/11/16**
9	Generation, demand scenarios analysis	20 days	Mon 22/02/16	Fri 18/03/16
10	Normal and fault conditions analysis	20 days	Wed 10/02/16	Tue 08/03/16
11	Harmonic analysis	2 days	Mon 22/02/16	Tue 23/02/16
12	Development of control strategy	150 days	Mon 11/04/16	Fri 04/11/16
13	Development of protection strategy	0 days	Fri 08/04/16	Fri 08/04/16
14	Q&A and approval	5 days	Mon 21/03/16	Fri 25/03/16
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~~	~~80 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~~	~~80 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**	**19 days**	**Tue 09/02/16**	**Fri 04/03/16**
22	Develop holistic condition monitoring equipment technical specification	11 days	Tue 09/02/16	Tue 23/02/16
23	Develop MVDC link technical specification	9 days	Tue 23/02/16	Fri 04/03/16
24	**Develoment of invitation to tender documents**	**47 days**	**Mon 07/03/16**	**Tue 10/05/16**
25	Develop invitation to tender documents for holistic condition monitoring equipment	15 days	Mon 07/03/16	Fri 25/03/16
26	Develop invitation to tender documents for MVDC link	45 days	Wed 09/03/16	Tue 10/05/16
27	**SDRCs**	**185 days**	**Fri 10/06/16**	**Fri 24/02/17**
28	**Publication of technical specification for monitoring syst**	**0 days**	**Fri 10/06/16**	**Fri 10/06/16**
29	**Publication of technical specification for the MVDC link**	**0 days**	**Fri 24/02/17**	**Fri 24/02/17**
30	**WP2 - MVDC Link**	**1089 days**	**Wed 11/05/16**	**Fri 10/07/20**
31	Procurement and vendor evaluation	73 days	Wed 11/05/16	Fri 19/08/16
32	Sign the contract	146 days	Tue 23/08/16	Tue 14/03/17
33	Equipment production	303 days	Wed 29/03/17	Fri 25/05/18
34	Factory acceptance test	135 days	Mon 08/01/18	Fri 13/07/18
35	Site preparation, civil, communications and electrical	195 days	Wed 16/01/19	Mon 14/10/19
36	Equipment delivery	15 days	Tue 15/10/19	Mon 04/11/19
37	Equipment installation	144 days	Tue 22/10/19	Fri 08/05/20
38	Site acceptance test	15 days	Fri 08/05/20	Thu 28/05/20
39	Commissioning	31 days	Fri 29/05/20	Fri 10/07/20
40	**SDRCs**	**0 days**	**Fri 10/07/20**	**Fri 10/07/20**
41	**Installation of MVDC link**	**0 days**	**Fri 10/07/20**	**Fri 10/07/20**
42	**WP3 - AC System**	**1007.5 days**	**Mon 07/03/16**	**Tue 14/01/20**
43	Detailed circuit design	335 days	Mon 07/03/16	Fri 16/06/17
44	Procurement	15 days	Mon 21/01/19	Fri 08/02/19
45	Wayleaves	734 days	Mon 20/06/16	Thu 11/04/19
46	Equipment delivery	5 days	Fri 10/05/19	Thu 16/05/19
47	Installation	160 days	Fri 17/05/19	Wed 25/12/19
48	Protection settings	2.5 days	Mon 06/01/20	Wed 08/01/20
49	Commissioning	1 day	Mon 13/01/20	Tue 14/01/20
50	**WP4 - Holistic Condition Monitoring**	**256 days**	**Tue 09/02/16**	**Tue 31/01/17**
51	Procurement and vendor evaluation	96 days	Tue 09/02/16	Tue 21/06/16
52	Sign the contract	3 days	Wed 22/06/16	Fri 24/06/16
53	Equipment production	90 days	Mon 13/06/16	Fri 14/10/16
54	Factory acceptance test	11 days	Fri 14/10/16	Fri 28/10/16
55	Site preparation	30 days	Mon 17/10/16	Fri 25/11/16
56	Equipment delivery	10 days	Mon 17/10/16	Fri 28/10/16
57	Equipment installation	20 days	Mon 21/11/16	Fri 16/12/16
58	Communications	10 days	Mon 19/12/16	Fri 30/12/16
59	Site acceptance test	2 days	Mon 23/01/17	Tue 24/01/17
60	Commissioning	5 days	Wed 25/01/17	Tue 31/01/17
61	**SDRCs**	**0 days**	**Tue 31/01/17**	**Tue 31/01/17**
62	**Commissioning of Holistic Condition Monitoring systems**	**0 days**	**Tue 31/01/17**	**Tue 31/01/17**
63	**WP 5 - Data Analysis**	**605 days**	**Tue 01/01/19**	**Fri 23/04/21**
64	Gather Holistic Condition Monitoring data	600 days	Tue 01/01/19	Fri 16/04/21
65	MVDC system setting adjustments	250 days	Mon 04/05/20	Fri 16/04/21
66	Develop policy documents for MVDC applications	175 days	Mon 13/07/20	Fri 12/03/21
67	Report writing	30 days	Mon 15/03/21	Fri 23/04/21
68	**SDRCs**	**0 days**	**Fri 23/04/21**	**Fri 23/04/21**
69	**Publication of Holistic Condition Monitoring data**	**0 days**	**Fri 23/04/21**	**Fri 23/04/21**
70	**Publication of operation performance of MVDC converte**	**0 days**	**Fri 23/04/21**	**Fri 23/04/21**
71	**WP 6 - Dissemination**	**1339 days**	**Wed 01/06/16**	**Fri 16/07/21**
72	**6 monthly progress report**	**1316 days**	**Mon 06/06/16**	**Fri 18/06/21**
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 01/06/20	Fri 12/06/20
81	Report 9	10 days	Mon 07/06/21	Fri 18/06/21
82	**Workshops**	**1098 days**	**Mon 06/02/17**	**Tue 20/04/21**
83	MVDC Technical Design	2 days	Mon 06/02/17	Tue 07/02/17
84	Real-Time Circuit Condition Monitoring	2 days	Mon 05/02/18	Tue 06/02/18
85	MVDC Manufacturing and Site Preparation	2 days	Mon 04/02/19	Tue 05/02/19
86	MVDC Link Performance Review	2 days	Mon 19/04/21	Tue 20/04/21
87	**Webinars**	**1236 days**	**Mon 03/10/16**	**Fri 25/06/21**
88	MVDC technology and Supplier Engagement	50 days	Mon 03/10/16	Fri 09/12/16
89	Real-Time Circuit Condition Monitoring systems for AC and DC applications	50 days	Mon 02/10/17	Fri 08/12/17
90	MVDC manufacturing	50 days	Mon 01/10/18	Fri 07/12/18

ANGLE-DC

ID	Task Name	Duration	Start	Finish
91	Cable ageing mechanism in AC and DC conditions	50 days	Mon 19/04/21	Fri 25/06/21
92	MVDC performance in real-life and data analysis	50 days	Mon 19/04/21	Fri 25/06/21
93	**LCNI conference**	**784 days**	**Wed 23/11/16**	**Fri 22/11/19**
94	LCNI 2016	3 days	Wed 23/11/16	Fri 25/11/16
95	LCNI 2017	3 days	Wed 22/11/17	Fri 24/11/17
96	LCNI 2018	3 days	Wed 21/11/18	Fri 23/11/18
97	LCNI 2019	3 days	Wed 20/11/19	Fri 22/11/19
98	**SPEN innovation website update**	**1057 days**	**Wed 01/06/16**	**Wed 17/06/20**
99	6 monthly update 1	3 days	Wed 01/06/16	Fri 03/06/16
100	6 monthly update 2	3 days	Wed 14/12/16	Fri 16/12/16
101	6 monthly update 3	3 days	Tue 30/05/17	Thu 01/06/17
102	6 monthly update 4	3 days	Thu 14/12/17	Mon 18/12/17
103	6 monthly update 5	3 days	Wed 30/05/18	Fri 01/06/18
104	6 monthly update 6	3 days	Wed 12/12/18	Fri 14/12/18
105	12 monthly update 7	3 days	Wed 29/05/19	Fri 31/05/19
106	12 monthly update 8	3 days	Mon 15/06/20	Wed 17/06/20
107	**Close-down report**	**120 days**	**Mon 01/02/21**	**Fri 16/07/21**
108	First draft preparation	60 days	Mon 01/02/21	Fri 23/04/21
109	Internal review	30 days	Mon 26/04/21	Fri 04/06/21
110	External consultation	30 days	Mon 26/04/21	Fri 04/06/21
111	Final submission	30 days	Mon 07/06/21	Fri 16/07/21
112	**SDRCs**	**0 days**	**Fri 16/07/21**	**Fri 16/07/21**
113	**Effective Knowledge Dissemination**	**0 days**	**Fri 16/07/21**	**Fri 16/07/21**



Project: ANGLE-DC Project Plan
Date: Fri 05/06/20

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 · Baseline · Baseline Milestone · Baseline Summary · Progress · Deadline · Slippage

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SECTION 5 PROGRESS AGAINST BUDGET

Below is a summary of the total project budget position from commencement to June 2020. The budget plan refers to the revised budget approved in the January 2020 project direction.

In line with the funding arrangements, SPM have contributed to costs incurred for a proportion of the expenditure in-line with the revised 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]	Labour is lower than plan due to a mix of less engineering hours and some contract resources.
Equipment	[redacted]	[redacted]	[redacted]	Equipment is lower than plan due to some costs not yet incurred.
Contractors	[redacted]	[redacted]	[redacted]	Contractor spend is higher than plan mainly due to additional building and AC cable costs.
IT	[redacted]	[redacted]	[redacted]	
Travel & Expenses	[redacted]	[redacted]	[redacted]	Travel expenses are lower than forecast due to not requiring extensive international travel.
Contingency & Others	[redacted]	[redacted]	[redacted]	Contingency utilised on building and AC cable overspend.
Totals	[redacted]	[redacted]	[redacted]	

In explanation of the budget figures: -

Labour – As the project labour resources had been supplemented with contract resource the labour costs are currently less that what was originally profiled.

Equipment – Some payments for equipment have not yet been made due to delays in the installation program.

Contractors – The invoices and costs for the converter buildings and the new AC cable are currently being finalised. These are higher than forecast due to various reasons. On the AC cable; directional drilling requirements for Network Rail, landowner and consent issues, and Local Authority/Traffic Management have all contributed to additional costs. The buildings have been slightly higher than forecast mainly due to site conditions and delays.

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 have been incurred). The unused budget has been allocated to the construction/installation works.

Contingency – Some of the contingency budget has been utilised for the contractor works. This has mainly been the AC cable installation and building works, plus various amounts for contract consultancy works for understanding DC effects near Network Rail assets.

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, no SDRCs were due for completion.

The project has delivered SDRC 4 in September 2018; however, SDRCs 5, 6 and 7 now have new dates due to a material change to the project caused by the MVDC building redesign. These new dates are reflected in Table 1.

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.	Complete	28/09/2018	Completion of FATS for MVDC convertors ahead of schedule. Report has been submitted to Ofgem.
SDRC - 5 Installation of MVDC Circuit	On Track	10/07/2020	On track to meet new SDRC 5 date.
SDRC 6 - Publication of Holistic Condition Monitoring data.	On Track	23/04/2021	On track to meet new SDRC 6 date.
SDRC 7 - Publication of operation performance of MVDC converters.	On Track	23/04/2021	On track to meet new SDRC 7 date.
SDRC 8 - Effective Knowledge Dissemination.	On Track	16/07/2021	On track to meet new SDRC 8 date.

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 last 12-month period of the project, are a detailed as follows:

Stakeholder Engagement:

The Project has focused on stakeholder engagement over the past twelve months, mainly with parties affected by the construction activities. The main learning outcome is to engage stakeholders early in order to have time to address their concerns.

This learning outcome is true of stakeholders like residents living on the delivery route of the transformers and large plant items. The Project was able to liaise with the residents and work with them to minimise disruption and prevent issues for the construction.

Contract Management

There have been several difficulties with contractor relationships through the latter stages of the project delivery, in particular with the MVDC equipment supplier. The issues have mainly been in regard to contract scope and lack of clarity of elements which the contractor seen as additional, whereas the project team understood things to be included. The details provided at the tender stage need to be sufficiently in depth to ensure there is no ambiguity for variation creepage.

SECTION 9 INTELLECTUAL PROPERTY RIGHTS (IPR)

The project is not funding the development of any technology which should create foreground IPR. We do not anticipate any further changes to this approach for any subsequent project partners.

SECTION 10 RISK MANAGEMENT

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 project. All identified risks are list under four major risks areas (technical, procurement, operational and project management) and are listed in Table 2.

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

Risk 1.03 **Harmonic interference:** Lack of converter modelling information for AC/DC interactions studies, which will put the Common Safety Method Risk Evaluation and Assessment approval at risk. This risk has risen from 25/40 to 30/40.

Risk 2.03 **Cost of Installation:** Following the energisation of the circuit and final contract settlement, this risk is now closed.

Risk 2.04 **Easements/ wayleaves:** Following the negotiation and bank transfer with the various land agents, this risk is now closed.

Risk 2.06 **Damaged equipment:** Following the delivery of all items to site, the risk has not materialised, and this risk is now closed.

Risk 2.08 **Delay in delivery of Converters** Following the delivery of all items to site, the risk has not materialised, and this risk is now closed.

Risk 2.11 **Delay in delivery of network control system:** A continuing risk is the delivery of the network level control system. This item is critical to the operation of the MVDC link and the converter commissioning cannot be completed without it. SP Energy Networks has awarded a contract and begun development. This risk is reduced slightly from 25/40 to 20/40.

Risk 4.01 **Higher costs:** There two commercial contracts that are yet to be closed, but these are expected to remain within budget contingency. The MVDC supplier has submitted additional costs claims related to working during the COVID 19 crisis. Overall, the score for this risk has slightly increased from 25/40 to 28/40.

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 cable's 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.	30
1.04	Earthing with DC	High DC earth returns 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

ANGLE-DC

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. SP Energy Networks 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					
2.09	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 SP Energy Networks	As a large customer, the selected MVDC link supplier modifies a HVDC converter design to curry favour with SP Energy Networks 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
2.11	Delay in delivery of network control system.	Delay in delivery of network level control system.	Delay in delivery of SDRCs 5, 6 and 7.	1) Run second tender as early as possible. 2) Use supplier with extensive prior experience. 3 Work closely with the supplier and SP Energy Networks real time systems to ensure smooth delivery.	20

ANGLE-DC

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
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. 5. Combine building and AC system tenders into one contract and one supplier.	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

ANGLE-DC

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
4. Project Management Risks					
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