NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

JUNE 2019

ANGLE-DC

Version:	1.0	
Authored by:	Andrew Moon	– Senior Engineer and Project Manager
	Kevin Smith	– Lead Engineer and Principal Project Manager
Approved by:	James Yu	– Future Networks Manager

Table of Contents

SECTION 1 EXECUTIVE SUMMARY

1.1. Summary

The key achievements for the reporting period include: (1) The commencement of civil construction activities at Bangor and Llanfair substations, (2) the mobilisation of the AC circuit civil construction contractor, (3) the award and initial development of the network level control system and (4) the completion of the harmonic resonance study for the rail safety case.

Despite the progress that has been made, several key risks remain outstanding. These include successful delivery of the AC circuit civils element, development of the network control system, harmonic interference on the Britannia Bridge 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 2018 and June 2019. It also sets out work due to be carried out between June and December 2019.

1.3. Project Progress Highlights

The MVDC Link is now envisaged to be commissioned in early May 2020, given the latest project developments. Significant and commendable efforts have been put in by the project team and SPEN senior management to rectify and minimise the delays associated with the building work (caused by the change of specifications).

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 five Steering Board meetings, two each year from June 2016 until June 2018. The next will take place in August 2019.

Work Package 1 – Detailed Design

Detailed modelling of the bridge electromagnetic environment has progressed, with the resonance study completed and accepted in principle by network rail. [redacted] The deadline has been extended to December 2019, at which point the Common Safety Method -Risk Evaluation and Assessment safety justification report should be presented to the Electrification – System Review Panel.

In May 2018, the Project decided to re-run the control system, tender with 3 – additional suppliers with an increased budget following non-complaint returns in the 1st tender. The tender was closed in June 2018, with Nortech Management awarded the contract. The work program will take place between May 2019 and Q1 2020.

Work Package 2 – MVDC Link

The MVDC converter transformers were transported to a SPEN grid site in Cheshire for longer term storage in Jan 2019. During Q4 2019, these will be transported to their final locations at Llanfair PG and Bangor Grid and will undergo final condition assessment ahead of commissioning.

The converter modules have been transported to Leicester for long term storage following the factory systems tests in May 2018. In December 2018, the hardware in Loop simulations were carried out in Berlin, which used the MVDC converter control cabinets to test the complete simulated MVDC system in real time. SPEN witnessed the analogue and digital input and outputs to the interface cabinets and control response signals. [redacted]. Following the testing, the control cabinets were also transported to Leicester for long term storage in January 2019.

[redacted]

In late June 2018, the final prices for the buildings were received. The best prices received were almost double the value budgeted for the buildings. Between July and September 2018, a considerable amount of effort was put in to re-engineer the building design to bring the cost back to within the budget and contingency value. The building was retendered to suppliers releasing a sufficient saving for the project to continue. However this re-engineering, re-design and re-tendering pushed the building completion date back to October 2019. [redacted]

The buildings construction work began in February 2019, and will be completed in October 2019. Equipment installation is planned to take place between November 2019 and May 2020.

Work Package 3 – AC System

The tender for the AC cable was awarded in January 2019. A program has been submitted by the supplier, which concludes the AC cable commissioning in Q4 2019. A safety case for directional drill was submitted to Network Rail in Q4 2018 and the Project is awaiting the outcome of the Network Rail review. Wayleaves for the Bangor Fields had to be renegotiated again due to the land passing to a new landowner. A wayleave for the Llanfair field is being finalised.

In the next 6-months SP Energy Networks will appoint a directional drilling contractor to carry out the directional drill and the cable civils contractor will lay the ducts along the routes and install the AC cable.

Work Package 4 – Holistic Cable Condition Monitoring System

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.

Work Package 6 – Knowledge Dissemination

In H2 2018, the Project presented at the HVDC operators forum and Cigré 2018. A paper has been accepted and submitted to the 13th PES PowerTech Conference in Milan. A presentation will be given at this conference in June 2019.

1.4. Business Case

The high costs of the buildings triggered a review of the business case for the project in June 2018. The outcome of the review concluded the building costs needed to be reduced to leave enough contingency for the remainder of the project. The project carried out a redesign process and retender designs of reduced scope, which achieved sufficient savings to allow the project to continue.

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

- Lack of converter modelling information for AC/DC interactions studies, which will put the Common Safety Method Risk Evaluation and Assessment approval at risk.
- The approval of the Network Rail horizontal directional drill safety case in time for receiving pit access on the Bangor University playing grounds.

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

Between June 2018 and June 2019 project progress has been made in three key areas, (1) Completion of the tender process for the MVDC converter buildings and the start of construction. (2) Completion of the cable tender and (3) Completion of the control system tender and commencement of development works.

2.1.1 Common Safety Method Risk Assessment

A summary of the harmonic resonance study was issued to Network Rail in Q4 2018, which has received approval in principle and will be part of the package of evidence for the safety case. The converter failure modes analysis requires information from a commissioning standard prerequisite called an AC/DC Interaction study. This study would provide information on which AC network and converter operation states give rise to control system instabilities and effects on the DC cable current. [redacted]

During H2 2019, the Phase I work must be concluded to avoid commissioning delay. The deadline has been extended to December 2019.The CSM-REA safety justification report will be presented to the E-SRP in Q1 2020 at the latest. 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, now starting between April 2020 and July 2020.

2.1.2 Network Level Controllers

The re-tender for the control system was closed in June 2018.Nortech Energy management have been awarded the contract and they are working with SPEN in the development phase of the work. The development, design and installation work will take 9-12 months to complete, with commissioning from June 2019 to July 2020. The risk of high control system procurement costs have not materialised and the Project is working to ensure the control system remains within budget.

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 standards have completed FATs for the most of the main plant items. These items are the converter modules, transformer, DC switchgear and line reactors. Temporary storage arrangements the main plant items are detailed below.

2.2.1 Converter Modules

SP Energy Networks summarised the FAT documentation and successfully completed SDRC 4 in H2 2018. Following the FATs, the modules went into long term storage in Leicester, ready for shipment to site in April 2020.

2.2.2 Transformers

Following issue of the testing results, SP Energy Networks confirmed the approval of the four transformer units in Q3 2018.

[redacted] The transformers were transported to a SPEN bunded site in Cheshire and underwent filling for long term storage.

Between January and October 2019, the transformers will undergo periodic inspections and oil testing to check for any deterioration and moisture ingress. During Q4 2019, the transformers will be transported to their final locations at Llanfair PG and Bangor Grid and will undergo final condition assessment ahead of commissioning.

2.2.3 DC Switchgear

[redacted]

During mid-2019, the approvals process will begin ready for shipment in October 2019. Details of the testing results and documentation shall be provided in the next annual report.

2.2.4 DC Line Reactors

The approvals process concluded in September 2018, following eventual agreement on the test schedule. SPEN presence at the factory proved beneficial, ensuring all units underwent testing to the agreed specification. The reactors will undergo final condition assessment on site ahead of commissioning.

In Q4 2018, the reactors were shipped to the UK for long term storage until October 2019.

2.2.5 Factory System Tests and Commissioning Plan

In December 2018, the FST went ahead in line with the testing documentation provided by the MVDC converter supplier. SP Energy Networks and the MVDC converter supplier have agreed the onsite commissioning test plan, a pre-requisite before the system is tested and commissioned at site. As there is no specific standard for commissioning an MVDC link,

therefore some adaptation of the HVDC standard has been carried out in detail and agreed with GE. [redacted].

In H2 2019, the commission procedures and recording templates will be reviewed and the final file structure and contents will be finalised. The Project is consulting internally with stakeholders on the contents of the final file documentation, ready for business hand over post project completion.

2.3. MVDC Converter Buildings

Following the final BaFO round, the supplier costs had unexpectedly increased further over previous submissions. The planned award date of June 2018 was cancelled and a business case review was carried out to determine the best solution to address the tender returns being significantly higher than the project budget allowed. Following the review of several options, the Project decided to redesign the buildings to reduce material costs as far as practicable and re-tender the design to existing suppliers for a short duration tender. The redrafting of drawings and specifications took several months. The BaFO prices for the redesigned buildings were returned in October 2018 and SPEN decided the savings were sufficient enough to continue with the Project. Following approval, the building contract for both sites was awarded to NRS in January and the KO meeting and mobilisation took place in February 2019. As of June 2019, the buildings works are on track, with Llanfair building construction staggered ahead of Bangor building by 2 months.

Over the next 6 months, both the buildings will see construction pass the foundation level to completion in late Oct 2019. The GE will then have access and install their equipment into Q1 2020.

[redacted]

2.4. Work Package 3 – AC System

In October 2018, the cable tender was split from the buildings and run in parallel. Prices returned were above initial estimates, but within budget. The contract was awarded to cable

civils supplier A.E. Yates in March 2019. In April 2019, SPEN held a kick off meeting with cable contractor and a site visit with Bangor University to arrange access for the HDD reception pit. Bangor University have agreed to allow SPEN access to their playing fields, on the condition the fields are reinstated by Sept 2019. This date is therefore a critical date for the cable installation. In parallel, SPEN has submitted the final stage 3 safety case documents to Network Rail, which should be approved by July 2019. This decision lies on the critical path for installation of the AC cable and a key risk to meeting the September date for playing field reinstatement.

SPEN has been in discussion with Highways regarding the location where the cable crosses the A55 Bridge at the Llanfair PG housing estate. SPEN have dug extra trial holes at the bridge, focusing on the expansion joints, which form a barrier to the cable lay. Only 2 off 150mm ducts are available, so SPEN as assessing the best way across the A55 with a reduced set of ducts. This is currently a risk to delivery.

In the next 6-months SP Energy Networks will appoint a directional drilling contractor to carry out the directional drill, and AEY Yates lay the ducts along the routes and install the AC cable. The work will begin in July and run to Oct 2019. The ducts will be installed up until September 2019 to allow for the HDD completion, and the cable will be pulled, jointed and commissioned by early November 2019.

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 Q1 2019, 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.

2.6. Work Package 6 – Knowledge Dissemination

In H2 2018, the Project presented at the HVDC operators forum at the HVDC test centre in Cumbernauld. The Project also presented a paper at Cigré 2018. A future paper has been accepted and submitted to the 13th PES PowerTech Conference in Milan. A presentation will be given at this conference by Cardiff University in June 2019. The Project also attended a technical tour of the Flexible Power Link installation in Exebridge in May 2019.

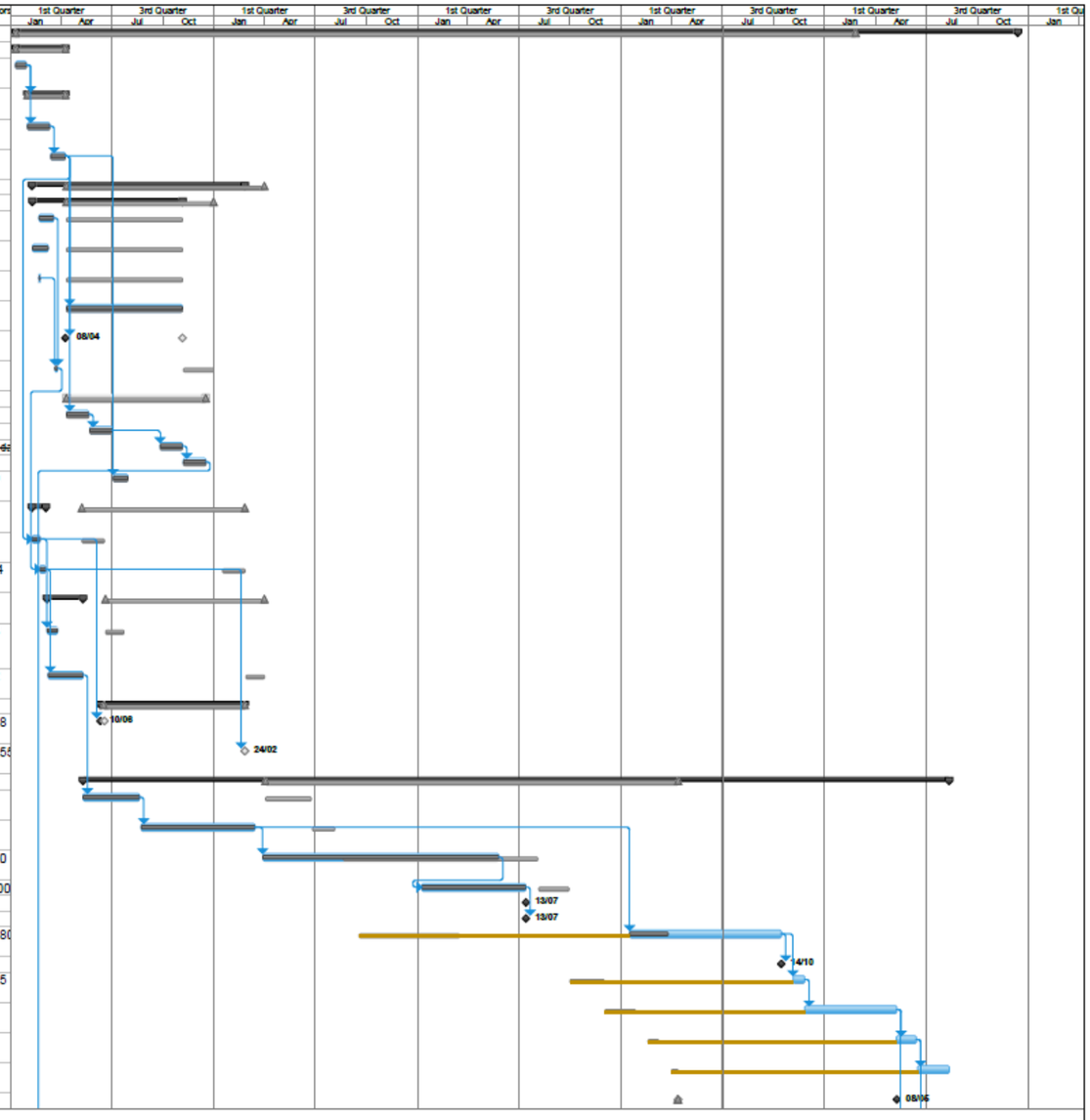
Over the next 12 months, the webinar on the MVDC converter site preparation will be held, taking place in December 2019. This has been delayed by 10 months due to the site works delay. The Project will be presenting this years' progress at LCNI 2019 and submitting a paper to Cigré 2021, on the Network level control system, in May 2020.

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	Predecessors
1	**ANGLE-DC**	**1286 days**	**Mon 11/01/16**	**Fri 11/12/20**	
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**	3
5	Identify project partners	30 days	Mon 01/02/16	Fri 11/03/16	3
6	Develop collaboration agreement with project partners	20 days	Mon 14/03/16	Fri 08/04/16	5
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	6
13	Development of protection strategy	0 days	Fri 08/04/16	Fri 08/04/16	6
14	Q&A and approval	5 days	Mon 21/03/16	Fri 25/03/16	11,9
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~~	6
17	~~Procurement for cable test~~	~~30 days~~	~~Mon 23/05/16~~	~~Fri 01/07/16~~	16
18	~~Cable capability test~~	~~30 days~~	~~Mon 25/09/16~~	~~Fri 04/11/16~~	17FS+60 d
19	~~Cable capability evaluation report~~	~~30 days~~	~~Mon 07/11/16~~	~~Fri 16/12/16~~	18
20	MVDC market research update	20 days	Mon 04/07/16	Fri 29/07/16	6FS+60 days
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	6FS-44 days
23	Develop MVDC link technical specification	9 days	Tue 23/02/16	Fri 04/03/16	14FS-24 days
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	22FS+8 days
26	Develop invitation to tender documents for MVDC link	45 days	Wed 09/03/16	Tue 10/05/16	23FS+2 days
27	**SDRCs**	**185 days**	**Fri 10/06/16**	**Fri 24/02/17**	
28	Publication of technical specification for monitoring system	0 days	Fri 10/06/16	Fri 10/06/16	22FS+78 days
29	Publication of technical specification for the MVDC link	0 days	Fri 24/02/17	Fri 24/02/17	23FS+25 days
30	**WP2 - MVDC Link**	**1110 days**	**Wed 11/05/16**	**Mon 10/08/20**	
31	Procurement and vendor evaluation	73 days	Wed 11/05/16	Fri 19/08/16	26
32	Sign the contract	146 days	Tue 23/08/16	Tue 14/03/17	31FS+1 day
33	Equipment production	303 days	Wed 29/03/17	Fri 25/05/18	32FS+10 days
34	Factory acceptance test	135 days	Mon 08/01/18	Fri 13/07/18	33FS-100
35	**SDRC**	**0 days**	**Fri 13/07/18**	**Fri 13/07/18**	
36	Factory Acceptance Test of MVDC Converters	0 days	Fri 13/07/18	Fri 13/07/18	34
37	Site preparation, civil, communications and electrical	195 days	Wed 16/01/19	Mon 14/10/19	32FS+480 days
38	Building Completion	0 days	Mon 14/10/19	Mon 14/10/19	37
39	Equipment delivery	15 days	Tue 05/11/19	Mon 25/11/19	37FS+15 days
40	Equipment installation	119 days	Tue 26/11/19	Fri 08/05/20	39
41	Site acceptance test	26 days	Fri 08/05/20	Fri 12/06/20	40FS-1 day
42	Commissioning	41 days	Mon 15/06/20	Mon 10/08/20	41
43	**SDRCs**	**0 days**	**Fri 08/05/20**	**Fri 08/05/20**	



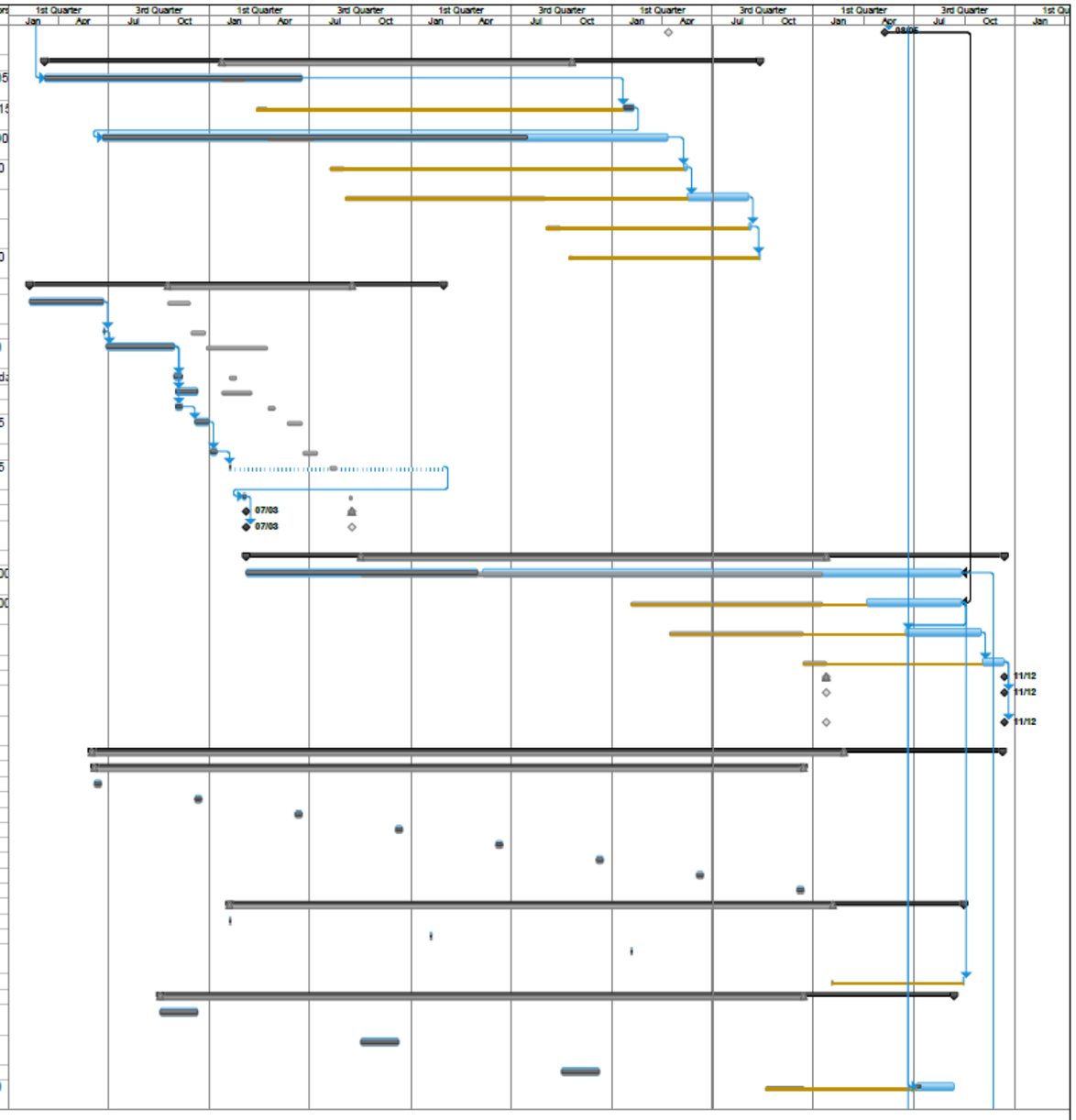
Project: ANGLE-DC Project Plan
Date: Tue 02/07/19

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

Page 1

ANGLE-DC

ID	Task Name	Duration	Start	Finish	Predecessors
44	Installation of MVDC link	0 days	Fri 08/05/20	Fri 08/05/20	40
45	**WP3 - AC System**	**929 days**	**Mon 07/03/16**	**Wed 25/09/19**	
46	Detailed circuit design	335 days	Mon 07/03/16	Fri 16/06/17	19FS-205 days
47	Procurement	15 days	Mon 21/01/19	Fri 08/02/19	46FS+415 days
48	Wayleaves	734 days	Mon 20/06/16	Thu 11/04/19	47FS-690 days
49	Equipment delivery	5 days	Fri 10/05/19	Thu 16/05/19	48FS+20 days
50	Installation	80 days	Fri 17/05/19	Wed 04/09/19	49
51	Protection settings	2.5 days	Thu 05/09/19	Mon 09/09/19	50
52	Commissioning	2.5 days	Mon 23/09/19	Wed 25/09/19	51FS+10 days
53	**WP4 - Holistic Condition Monitoring**	**537 days**	**Tue 09/02/16**	**Wed 28/02/18**	
54	Procurement and vendor evaluation	96 days	Tue 09/02/16	Tue 21/06/16	
55	Sign the contract	3 days	Wed 22/06/16	Fri 24/06/16	54
56	Equipment production	90 days	Mon 27/06/16	Fri 28/10/16	55FS-10 days
57	Factory acceptance test	11 days	Fri 28/10/16	Fri 11/11/16	56FS-1 da
58	Site preparation	30 days	Mon 31/10/16	Fri 09/12/16	56
59	Equipment delivery	10 days	Mon 31/10/16	Fri 11/11/16	56
60	Equipment installation	20 days	Mon 05/12/16	Fri 30/12/16	59FS+15 days
61	Communications	10 days	Mon 02/01/17	Fri 13/01/17	60
62	Site acceptance test	2 days	Mon 06/02/17	Wed 28/02/18	61FS+15 days
63	Commissioning	5 days	Wed 01/03/17	Tue 07/03/17	62
64	**SDRCs**	**0 days**	**Tue 07/03/17**	**Tue 07/03/17**	
65	Commissioning of Holistic Condition Monitoring systems	0 days	Tue 07/03/17	Tue 07/03/17	63
66	**WP 5 - Data Analysis**	**984 days**	**Wed 08/03/17**	**Fri 11/12/20**	
67	Gather Holistic Condition Monitoring data	923 days	Wed 08/03/17	Fri 25/09/20	44FF+100 days
68	MVDC system setting adjustments	125 days	Mon 06/04/20	Fri 25/09/20	44FF+100 days
69	Develop policy documents for MVDC applications	100 days	Mon 15/06/20	Fri 30/10/20	41
70	Report writing	30 days	Mon 02/11/20	Fri 11/12/20	69
71	**SDRCs**	**0 days**	**Fri 11/12/20**	**Fri 11/12/20**	
72	Publication of Holistic Condition Monitoring data	0 days	Fri 11/12/20	Fri 11/12/20	70
73	Publication of operation performance of MVDC converters	0 days	Fri 11/12/20	Fri 11/12/20	70
74	**WP 6 - Dissemination**	**1181 days**	**Wed 01/06/16**	**Tue 08/12/20**	
75	**6 monthly progress report**	**921 days**	**Mon 06/06/16**	**Fri 13/12/19**	
76	Report 1	10 days	Mon 06/06/16	Fri 17/06/16	
77	Report 2	10 days	Mon 05/12/16	Fri 16/12/16	
78	Report 3	10 days	Mon 05/06/17	Fri 16/06/17	
79	Report 4	10 days	Mon 04/12/17	Fri 15/12/17	
80	Report 5	10 days	Mon 04/06/18	Fri 15/06/18	
81	~~Report 6~~	~~10 days~~	~~Mon 03/12/18~~	~~Fri 14/12/18~~	
82	Report 7	10 days	Mon 03/06/19	Fri 14/06/19	
83	Report 8	10 days	Mon 02/12/19	Fri 13/12/19	
84	**Workshops**	**953 days**	**Mon 06/02/17**	**Tue 29/09/20**	
85	MVDC Technical Design	2 days	Mon 06/02/17	Tue 07/02/17	
86	Real-Time Circuit Condition Monitoring	2 days	Mon 05/02/18	Tue 06/02/18	
87	MVDC Manufacturing and Site Preparation	2 days	Mon 04/02/19	Tue 05/02/19	
88	MVDC Link Performance Review	2 days	Mon 28/09/20	Tue 29/09/20	68
89	**Webinars**	**1031 days**	**Mon 03/10/16**	**Fri 11/09/20**	
90	MVDC technoloigy and Supplier Engagement	50 days	Mon 03/10/16	Fri 09/12/16	
91	Real-Time Circuit Condition Monitoring systems for AC and DC applications	50 days	Mon 02/10/17	Fri 08/12/17	
92	~~MVDC manufaeturing~~	50 days	Mon 01/10/18	Fri 07/12/18	
93	Cable ageing mechanism in AC and DC conditions	50 days	Mon 06/07/20	Fri 11/09/20	68FS-60 days



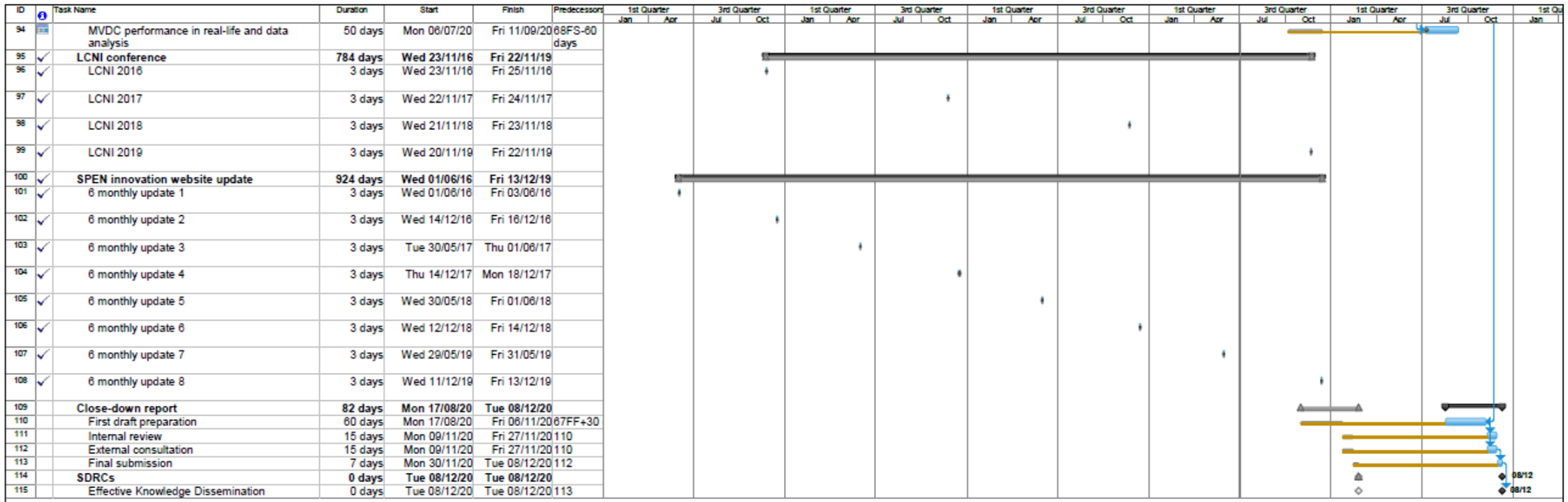
Project: ANGLE-DC Project Plan
Date: Tue 02/07/19

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

Page 2

ANGLE-DC

ID	Task Name	Duration	Start	Finish	Predecessors
94	MVDC performance in real-life and data analysis	50 days	Mon 06/07/20	Fri 11/09/20	68FS-60 days
95	**LCNI conference**	**784 days**	**Wed 23/11/16**	**Fri 22/11/19**	
96	LCNI 2016	3 days	Wed 23/11/16	Fri 25/11/16	
97	LCNI 2017	3 days	Wed 22/11/17	Fri 24/11/17	
98	LCNI 2018	3 days	Wed 21/11/18	Fri 23/11/18	
99	LCNI 2019	3 days	Wed 20/11/19	Fri 22/11/19	
100	**SPEN innovation website update**	**924 days**	**Wed 01/06/16**	**Fri 13/12/19**	
101	6 monthly update 1	3 days	Wed 01/06/16	Fri 03/06/16	
102	6 monthly update 2	3 days	Wed 14/12/16	Fri 16/12/16	
103	6 monthly update 3	3 days	Tue 30/05/17	Thu 01/06/17	
104	6 monthly update 4	3 days	Thu 14/12/17	Mon 18/12/17	
105	6 monthly update 5	3 days	Wed 30/05/18	Fri 01/06/18	
106	6 monthly update 6	3 days	Wed 12/12/18	Fri 14/12/18	
107	6 monthly update 7	3 days	Wed 29/05/19	Fri 31/05/19	
108	6 monthly update 8	3 days	Wed 11/12/19	Fri 13/12/19	
109	**Close-down report**	**82 days**	**Mon 17/08/20**	**Tue 08/12/20**	
110	First draft preparation	60 days	Mon 17/08/20	Fri 06/11/20	67FF+30
111	Internal review	15 days	Mon 09/11/20	Fri 27/11/20	110
112	External consultation	15 days	Mon 09/11/20	Fri 27/11/20	110
113	Final submission	7 days	Mon 30/11/20	Tue 08/12/20	112
114	**SDRCs**	**0 days**	**Tue 08/12/20**	**Tue 08/12/20**	
115	Effective Knowledge Dissemination	0 days	Tue 08/12/20	Tue 08/12/20	113



Project: ANGLE-DC Project Plan
Date: Tue 02/07/19

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

Page 3

SECTION 5 PROGRESS AGAINST BUDGET

Below is a summary of the total project budget position from commencement to June 2018. 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]	Labour is lower than forecast due mainly to the use of more contract resources.
Equipment	[redacted]	[redacted]	[redacted]	Equipment is lower than forecast due to project delays.
Contractors	[redacted]	[redacted]	[redacted]	Contractor forecast is lower than forecast due to project delays.
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 budget not yet utilised.
Totals	[redacted]	[redacted]	[redacted]	

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

In explanation of the budget figures: -

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

Equipment – The convert building works only commenced early 2019 and therefore the payments for the project equipment to suppliers is delayed from the original anticipated payment profiles.

Contractors – As the converter station construction works are ongoing only some payments have been incurred to date. The main cable laying is about to start therefore these 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 have been incurred).

Contingency – there has been no contingency budget used to date. However this will be utilised to complete the works due to some unexpected costs.

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 are due for completion.

The project has delivered SDRC 4 in September 2018; however SDRCs 5, 6 and 7 will not be met due to a 6-month delay with the building design, procurement and construction.

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/ Commissioning of Converters.	Delayed	08/05/2020	Not started, but this will not be met on time because of building construction delays. Original date was 12/04/2019.
SDRC 6 - Publication of Holistic Condition Monitoring data.	Delayed	11/12/2020	DC ageing profile monitoring is dependent on SDRC 5 and will therefore also be missed. Original date was 23/01/2020.
SDRC 7 - Publication of operation performance of MVDC converters.	Delayed	11/12/2020	Not started; this will not be met on time because of building construction delays. Original date was 23/01/2020.
SDRC 8 - Effective Knowledge Dissemination.	On Track	08/12/2020	Project continues to disseminate above program requirements.

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 Network Rail, and their safety concerns for the HDD, or residents living near by the construction site concern about traffic and noise. The Project was able to put appropriate measures in place to mitigate the impact on affected parties.

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.

Three 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 10/40 to 25/40

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 2.04 **Cost of installation of AC system is significantly higher than estimated:** The cable contract was award within budget. However, two risks remain outstanding to delivery. These are the Horizontal Directional Drill and A55 bridge crossing. The risk of AC system cost increase remains the same at 20/40.

Risk 4.01 **Higher costs:** Though the building costs are now known, there is some uncertainty regarding the delay costs. These costs are the becoming clearer, but a resolution of any additional costs will be required with the MVDC converter supplier to mitigate the risk. The cost of the network control system is more certain. Overall, the score for this risk has reduced has from 35/40 to 25/40.

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 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.	25
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

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					
2.03	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. 4. Combine building and AC system tenders into one contract and one supplier.	20
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

ANGLE-DC

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 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

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.	30
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