NETWORK INNOVATION COMPETITION

PROJECT PROGRESS REPORT

JUNE 2018

ANGLE-DC

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

This report details the progress of the Angle-DC project, focusing on the 4th 6-month period of the project, December 2017 to June 2018. It also details work due to be carried out in H2 2018.

1.2. Project Progress Highlights

The overall project is divided into 6 distinct work packages and the Project's managers' report separates the project progress by these key areas. The project has held five Steering Board meetings, two each year from June 2015.

Work Package 1 – Detailed Design

Detailed modelling of the bridge electromagnetic environment has progressed but has faced a considerable delay against the original plan, due to unanticipated modelling pre-requisites. The deadline has been extended to December 2018, at which point the Common Safety Method -Risk Evaluation and Assessment safety justification report will be presented to the Electrification – System Review Panel.

In February 2018, a tender pack for the supply of a both the central and back-up controllers, was issued to six suppliers. The Project decided to re-run the tender with 3 – additional suppliers with an increased budget following non-complaint returns. This should be concluded July 2018.

Work Package 2 – MVDC Link

GE Power Conversion had placed orders for three of the four main plant items by Jan 2018 and SP Energy Networks have been reviewing the design and testing over the past 6-months. The converter modules were deemed to have successfully completed Factory Acceptance Testing (FAT) in March 2018. During May 2018, FAT certificates for two converter transformers were signed-off by the SP Energy Networks representative. The approvals process for the DC switchgear is still ongoing and FAT will take place before shipment to site. For the DC line reactors, several testing items have yet to be agreed, so work on approving this main component will to be concluded in H2 2018.

Following completion of the module FATs, two of the 24-modules were relocated to GE Power Conversion's Berlin testing facility for Factory System Tests over an 8-week period (from April to June 2018).

[redacted]

The MVDC converter building tender period has been delayed by several months due to technical queries and consideration of combining the buildings and new cable lay with a single contractor to achieve maximum cost efficiency, together with several contractors the interested in delivering all elements. This is also driven in part due to the costs increasing considerably from those originally estimated. SP Energy Networks is now undertaking BAFO on these elements.

Work Package 3 – AC System

The tender for the back-up AC circuit was released to suppliers, with 10 bids received. The prices were higher than anticipated. The BAFO stage for the cable is currently taking place. Separate to the AC cable tender, a topographical and utility survey has been progressed for a directional drill underneath the Network Rail track on the south side of Britannia Bridge.

In the next 6-months SP Energy Networks will present a drilling method statement and safety case to Network rail, which will be assessed before work can proceed. The Project is negotiating the final wayleave for the AC cable route, which should be granted in Q3 2018.

Work Package 4 – Holistic Cable Condition Monitoring System

Due to the revised layout and positioning of the converter building, the Llanfair-PG Partial Discharge sensors have had to be removed from the overhead line terminal poles being relocated into another field. PD monitoring is still being carried out from the Bangor Grid substation. Eventually, the Llanfair PG PD sensors will be reinstalled within the DC switchgear panel. 12-months of AC PD trend data has been collected to date.

Work Package 6 – Knowledge Dissemination

During H1 2018, SP Energy Networks hosted a Real-Time Circuit Condition Monitoring workshop and presented at two international conferences. Presentations at an industrial forum and Cigré 2018 are planned over the next 6-months.

1.3. Business Case

As of December 2017, there has been no change to the business case of the project. However, escalating converter building costs are a cause for concern.

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. These are detailed in Section 8 of this report.

1.5. 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 six-months.

The main change in risk level within this reporting period comes from increased project costs associated with the MVDC converter building and AC system. The converter building construction delayed start will impact the project completion date.

SECTION 2 PROJECT MANAGER'S REPORT

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

2.1. Work Package 1 – Detailed Design

During the 5th 6-month period of the project, progress has been made in three key areas, (1) completion of the FATs for the converter modules and transformers, (2) completion of the noise propagation studies for both sites and (3) near completion of the tender process for the MVDC converter buildings.

2.1.1 Common Safety Method Risk Assessment

Detailed modelling of the bridge electromagnetic environment has progressed but has faced a significant delay against the revised plan; i.e. concluding Phase I work by June 2018. Delays have been caused by a modelling pre-requisite, which was not foreseen in H2 2017. This modelling pre-requisite involves modelling the converter AC harmonic impedance as viewed from the AC sides of the network. The work has a lead time of 16-weeks. Progress has been made on the AC network harmonic resonance sensitivity analysis and completion of the DC cable model.

During H2 2018, the Phase I work should be concluded by utilising GE Power Conversion harmonic transfer results with the DC cable model. The deadline has been extended to December 2018, at which point the CSM-REA safety justification report will be presented to the E-SRP. A decision on interim approval will then be given by Network Rail. Phase II work will seek to provide demonstration of compliance with safety requirements through testing and validation of EMI models and safety requirement assumptions. The Phase II work will be carried out as part of the converter commissioning, starting between December 2018 and June 2019.

2.1.2 Network Level Controllers

Following a PQQ in early October 2017, a tender pack, for the supply of a both the central and back-up controller, was issued to six suppliers. The Tender process took longer than planned and four bids were received from suppliers. Only two of four bids returned were within the available budget, but were not technically compliant. The Project decided to re-issue the tender with 3 additional suppliers to try and secure additional interest. Following re-release in mid-May 2018, the 2nd tender process is due to be completed by late June 2018.

During the next 6-months the selected supplier will need to work with SP Energy Networks to develop control system that meets the SoW specification. It is expected the design and installation work will take 9-12 months to complete, with commissioning planned for June 2019. The control system is a critical component to the operation of the MVDC link and therefore represents a risk to delivery of the MVDC commissioning. This risk is discussed in Section 10.

2.1.3 Acoustic Survey

The results of the acoustic survey became available in Q2 2018. The results, based on conservative values due to data not being available, show no requirement for sound attenuation at Bangor grid and a possible 15dB sound attenuation requirement at Llanfair PG.

In the next reporting period, SP Energy Networks will attempt to improve the sound sources data set and re-run the studies to determine what sound mitigation measures are necessary at Llanfair PG.

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

SP Energy Networks standards, referenced in the commercial contract, stipulate SP Energy Networks shall approve main plant items before the MVDC link can be deployed on the distribution network. These items are the converter modules, transformer, DC switchgear and line reactors. GE Power Conversion had placed orders for three of the four main plant items by Jan 2018 and SP Energy Networks have been reviewing the design and testing over the past 6-months. These were the converter modules, transformers and DC reactors.

2.2.1 Converter Modules

The converter module manufacturing proceeded following a design review by the SP Energy Networks approvals team. In parallel, the testing plan for modules was finalised and agreed, between SP Energy Networks and GE Power Conversion, before witnessing testing in Villebon Paris in March 2018. The project faced considerable difficulty extracting the testing specification information, from the supplier in a timely manner, to assess compliance with standards. Despite these challenges, the converter modules were deemed to have successfully completed Factory Acceptance Testing (FAT) in March 2018.

SP Energy Networks is now extracting the FAT testing documentation from GE Power Conversion Power Conversion to provide evidence for the SDRC 4 report in H2 2018.

2.2.2 Transformers

A Factory Acceptance Testing approach has been undertaken for the MVDC link transformers. This took place in five key stages: 1) Review of GE Power Conversion design information, 2) Factory Inspection, 3) A design review meeting, 4) Agreement of the testing plan and 5) Witness testing. Stages 1-4 took place between January and April 2018. [redacted]. Once the testing plan was agreed, SP Energy Networks witnessed the FATs of 2 of the 4 transformers. During May 2018, FAT certificates for these transformers were signed by a SP Energy Networks representative. [redacted]

Following issue of the testing results, SP Energy Networks will confirm the approval of the four transformer units in Q3 2018. These units will be shipped by GE Power Conversion Power Conversion following building completion.

2.2.3 DC Switchgear

The approvals process for the DC switchgear began in December 2018 following a review by SP Energy Networks of the GE Power Conversion procurement specification. [redacted]. During H2 2018, the manufacture and approvals process will take place for this plant item before shipment to site for installation. Details of the testing results and documentation shall be provided in the next 6-montly report.

2.2.4 DC Line Reactors

The DC line reactors approval is taking a similar approach to the transformer FAT approach. The reactors are a simpler component than the transformer, so less design information is required. The reactor manufacturer is familiar to SP Energy Networks, so the factory inspection stage has been omitted.

[redacted] At the end of Q3 2018, the reactor testing will be witnessed at the factory. In Q4 the Project should have all the testing documentation required to grant approval, provided the units pass each scheduled test.

2.2.5 Factory System Tests

It is a requirement of the HVDC testing standard to run a Factory System Test (FST) before onsite commissioning tests begin. SP Energy Networks and GE Power Conversion Power Conversion have agreed for the FSTs it is not practical to fully test the entire converter system and a reduced testing system is sufficient to demonstrate compliance with standards. Following completion of the module FATS, in March 2018, two of the 24-modules were relocated to GE Power Conversion's Berlin testing facility. The FSTs are taking place over 8-weeks, from April to June 2018.

[redacted].

In H2 2018, the FST should be completed and the Project team will ensure the required testing documentation is provided. SP Energy Networks and GE Power Conversion are currently

agreeing the onsite commissioning test program, a pre-requisite before the system is tested and commissioned on site. As there is no specific standard for a MVDC link, some adaptation of the HVDC standard will be required.

2.3. MVDC Converter Buildings

The MVDC converter buildings are being designed and procured by SP Energy Networks to meet the specifications required by GE Power Conversion. Since receiving GE Power Conversion's final building specification in late August 2017, and completing the HVACs specification in November 2017, SP Energy Networks has been undertaking a tender process with building suppliers. Following SP Energy Networks procurement guidelines, the tender period from release to award would normal take approximately 22-weeks. This award date has been delayed from April to June 2018 due to higher than anticipated buildings prices (which require higher level of justification and approval), as they are approximately double. The increased cost should be able to be covered by the project contingency budget. Several factors have contributed to higher than expected building prices, namely: supplier uncertainty with HVAC design, a 40% tender return rate and general shortage of available building suppliers. The planned building completion date has now been moved from August to near the end of Q4 2018.

SP Energy Networks has mitigated some of the risk of cost escalation by reviewing bids line by line, reviewing the sums and challenging suppliers, which has further added to delay in awarding the contract. SP Energy Networks is now undertaking BAFO and assessing the feasibility of awarding a single contract for the converter buildings and back-up AC system to one supplier to generate efficiency savings. This is discussed further in Section 2.4.

2.4. Work Package 3 – AC System

In Q1 2018, the tender for the back-up AC circuit was released to suppliers, with 10-bids received. As for the MVDC converter buildings, the prices were higher than anticipated, coming in at nearly 40% over budget. In May 2018, suppliers will re-submit their prices during the BAFO stage, which is hoped will reduce prices due to the high number of bidders. SP Energy Networks may consider if an award for one contract for the AC cable and converter buildings will reduce costs and avoid using more project contingency budget. Both the MVDC converter buildings and AC system costs are currently a significant risk to the project budget based on the early round tender prices.

Separate to the AC cable tender, following the absence of spare cable ducts across the Network Rail track on the South of Britannia Bridge, a topographical and utility survey has been progressed for a directional drill underneath the railway track. This work has required a line blockage to allow safe trackside access. A follow up trial hole visit is being arranged for June to ensure the most appropriate drill site on the bridge.

In the next 6-months, SP Energy Networks will present a drilling method statement and safety case to Network rail, which will be assessed before work can proceed. It is expected the assessment and approval will take 3-6-months and will be granted between September and December 2018. Commissioning of the AC cable is planned for Q1 2019. The Project is

negotiating the final wayleave for the AC cable route, which is planned for completion in Q3 2018.

2.5. Work Package 4 – Holistic Circuit Condition Monitoring System

In Q1 2018, substation cable diversions and relocation of the overhead line H-poles into an adjacent field was completed at Llanfair PG substation, in preparation for the building construction. The distant location of the poles revised positions posed difficulty in reconnecting the Partial Discharge sensors. As 12-months of AC cable trend data has already been collected, it was decided to avoid costly reconnection of the PD monitoring sensors. The PD monitoring is still being carried out from the Bangor Grid substation which has the majority of the cable section connected to it. Eventually, the Llanfair PG PD sensors will be reinstalled within the DC switchgear panel.

No HCCM activity is planned over the next 6-months and the HCCM server will also be moved into the converter substation building in Q1 2019 once the Bangor Converter substation is complete.

2.6. Work Package 5 – Data Analysis and Enhanced Learning

Collection of HCCM data began in February 2017 and will continue at the Bangor Grid substation end until Q1 2019, when the circuit is de-energised and the back-up AC circuit begins operation during the converter installation and commissioning. This data will be analysed and interpreted by the HCCM supplier HVPD and then reviewed by SP Energy Networks. This work has begun ahead of schedule with the first analysis and results presented at the HCCM workshop in February 2018.

2.7. Work Package 6 – Knowledge Dissemination

In February 2018, SP Energy Networks hosted a Real-Time Circuit Condition Monitoring workshop to industry experts at their training centre in Hoylake. The event was well received and generated interested in the Project and cable ageing mechanisms under DC operation.

In March 2018, SP Energy Networks presented at the IET Developments in Power Systems Protection Conference to showcase the protection strategy for the MVDC converter station.

In April 2018, SP Energy Networks was invited to present at the annual European Centre for Power Electronics DC Grids workshop in Aachen Germany. The conference was well attended by power electronic experts from across Europe. The conference demonstrated a high level of interest in MVDC technologies and recent advances being made in this area.

In H2 2018, SP Energy Networks will present at the HVDC Operators' Forum and a paper and poster at the Cigré 2018 Paris session. The highlights of knowledge sharing at these events will be discussed in the next 6-monthly report.

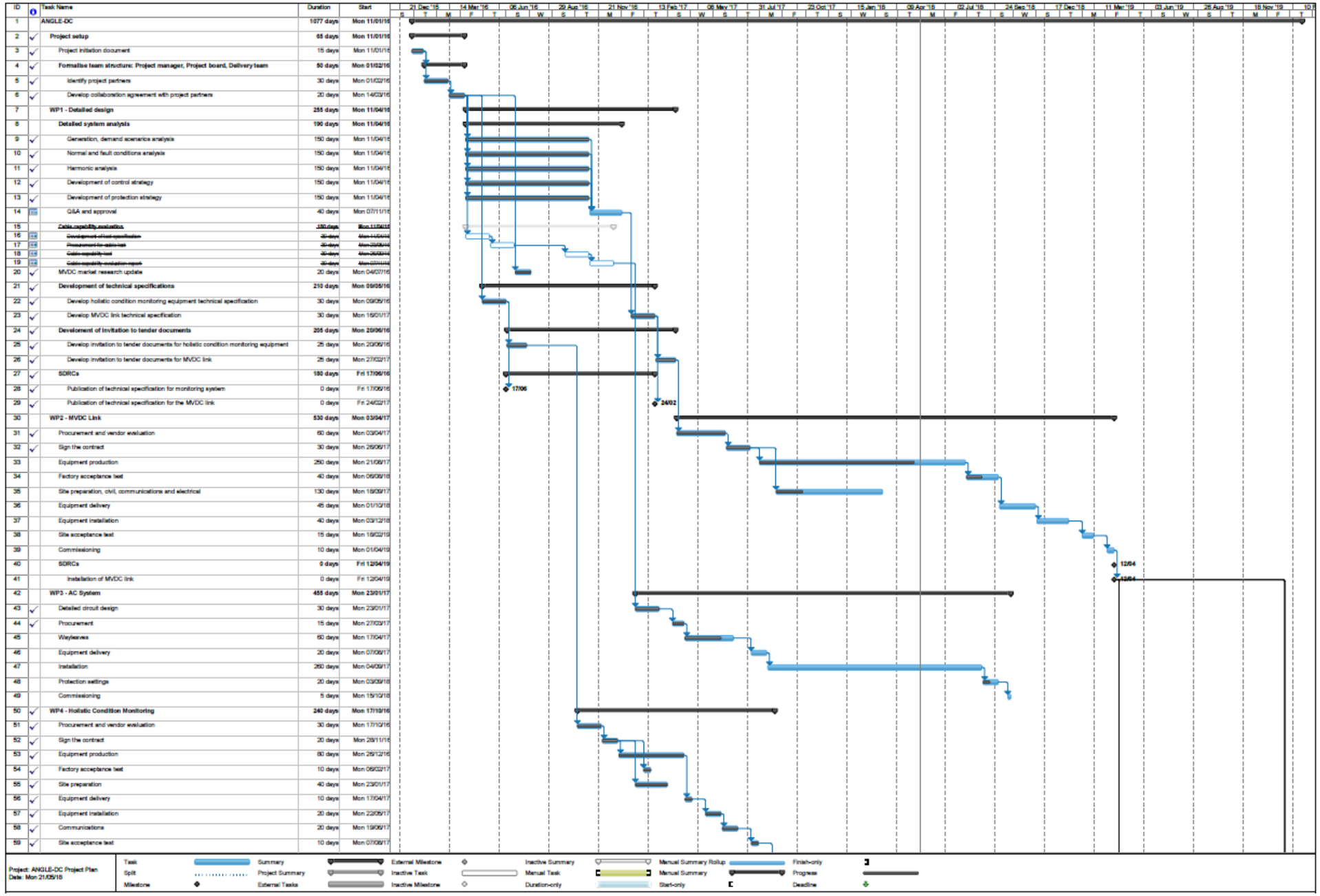
The project team has worked closely with the internal Health & Safety department of SP Energy Networks in the developing of safety requirements, procedures and documentation that will be needed for staff to safely operate and maintain an Angle-DC MVDC link. SP Energy Networks already has existing experience in this area, in particular due to the HVDC Western

Link 600kV connection. Building on this experience and whilst sharing the learning with the Health and Safety Executive (HSE), the Angle DC team presented their approach to safety management of the MVDC link to the HSE Principle Inspector at a meeting at the Western Link Flintshire Bridge site in April 2018.

SECTION 3 BUSINESS CASE UPDATE

To date, there has been no change to the business case of the project as the benefits of the Project cannot be evaluated until deployment. However, escalating costs are a cause for concern. Should MVDC converter buildings and network control system costs be as high, in real terms for future projects, it becomes difficult to envisage enough benefits released with a better Net Present Value than competing solutions, including conventional reinforcement.

SECTION 4 PROGRESS AGAINST PLAN



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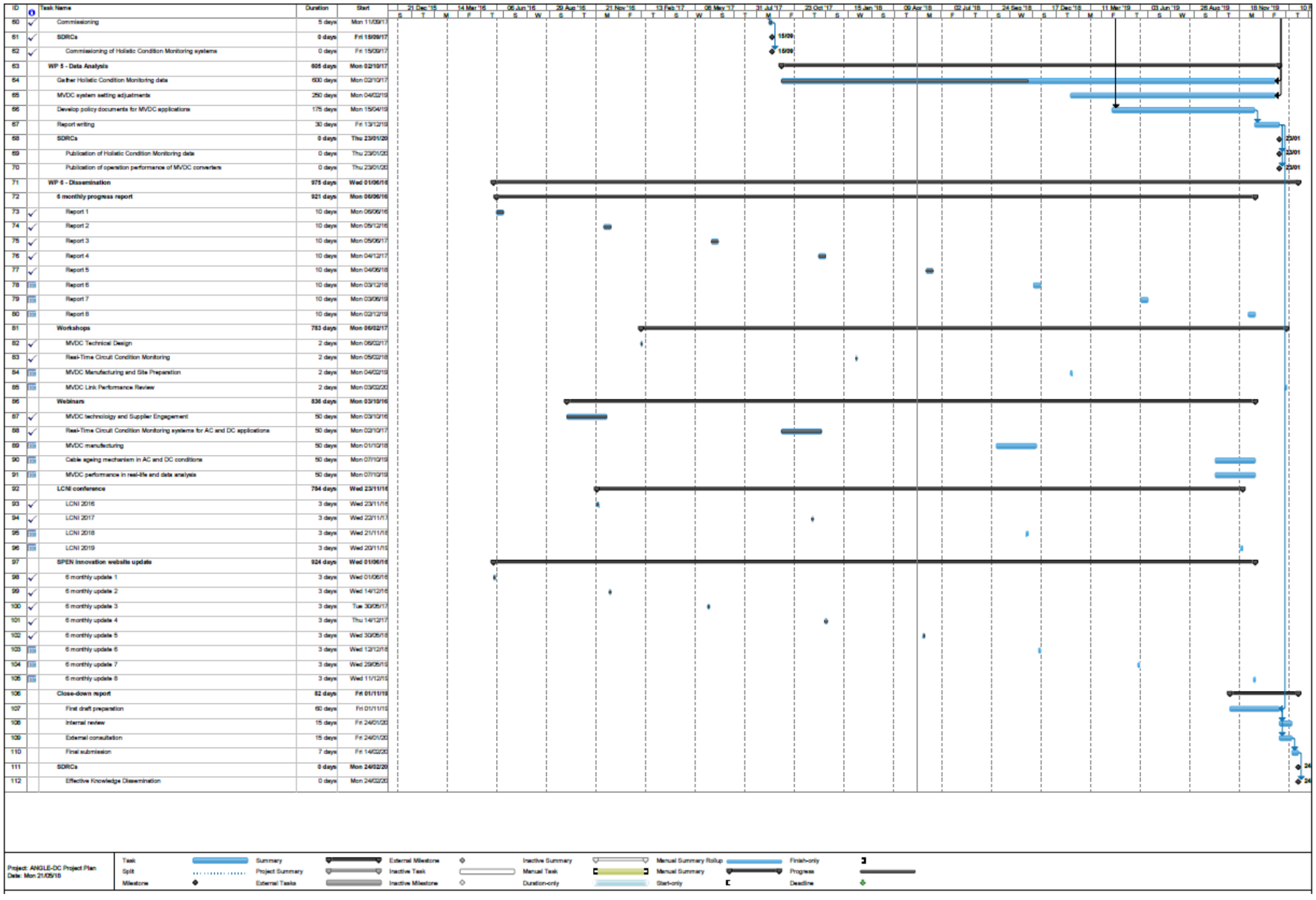

ID	Task Name	Duration	Start
60	Commissioning	5 days	Mon 11/09/17
61	SDRCs	0 days	Fri 15/09/17
62	Commissioning of Holistic Condition Monitoring systems	0 days	Fri 15/09/17
63	**WP 5 - Data Analysis**	**605 days**	**Mon 02/10/17**
64	Gather Holistic Condition Monitoring data	600 days	Mon 02/10/17
65	MVDC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

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]	Less internal labour used than profiled to date.
Equipment	[redacted]	[redacted]	[redacted]	Payment profile is later than originally planned.
Contractors	[redacted]	[redacted]	[redacted]	Main building and cable laying contractor costs not yet incurred.
IT	[redacted]	[redacted]	[redacted]	
Travel & Expenses	[redacted]	[redacted]	[redacted]	Project team has been less than expected.
Contingency & Others	[redacted]	[redacted]	[redacted]	No use of contingency has required to date.
Totals	[redacted]	[redacted]	[redacted]	

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

In explanation of the budget figures: -

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

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

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

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

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

SECTION 6 BANK ACCOUNT

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

SECTION 7 SDRC

This section describes the work to date associated with the project SDRCs. Over the reporting period, no SDRCs are due for completion.

The project is on track to deliver SDRC 4 by the end of H2 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.	On Track	28/09/2018	Completion of FATS for MVDC convertors ahead of schedule. Evidence is current being gathered from GE Power Conversion Power Conversion.
SDRC - 5 Installation of MVDC Circuit/ Commissioning of Converters.	Delayed	12/04/2019	Not started, but this will not be met on time because of building construction delays.
SDRC 6 - Publication of Holistic Condition Monitoring data.	Delayed	23/01/2020	DC ageing profile monitoring is dependent on SDRC 5 and will therefore also be missed.
SDRC 7 - Publication of operation performance of MVDC converters.	Delayed	23/01/2020	Not started; this will not be met on time because of building construction delays.
SDRC 8 - Effective Knowledge Dissemination.	On Track	16/04/2020	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 5th 6-month period of the project, are a detailed as follows:

MVDC Converter Design and Testing Standards: Several sources of standard are used in the Angle-DC project, namely International/British standards, ENA Technical Specifications and SP Energy Networks policy documentation. There has been difficulty encouraging the MVDC converter supplier to demonstrate compliance to the various standards for the major components of the MVDC converter. Throughout the equipment approvals process, the converter supplier has maintained SP Energy Networks only has a right to assess the procurement specification, for main plant items, and not on further detailed engineering design and testing. The supplier's preference is to provide minimum levels of information and issue declarations of conformance to various standards. SP Energy Networks has repeatedly stated the requirement to understand the design and testing in detail to assess adherence in critical areas such as quality and health and safety.

The learning outcome, regarding approvals, is to rigorously question and challenge suppliers on conformance to standards at tender stage in addition to stating the standards to be adhered to.

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 2.11 Delay in delivery of network control system: A new risk arising, in this reporting period, is the delay of the in the procurement 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 is working on completing the tender process in Q3 2018. This risk is introduced at 25/40.

Risk 2.04 Cost of installation of AC system is significantly higher than estimated: The first-round supplier prices were significantly higher than budgeted. A BaFO stage and efficiency savings should see these prices reduce. The risk of AC system cost increase has been raised from 10/40 to 20/40.

Risk 4.01 Higher costs: The cost for the AC cable and building are significantly higher than anticipated in December 2017. The building costs are approximately 90-100% higher than anticipated. The cable costs have been returned, with the lowest first stage bid at approximately 40% over budget. This leaves the project with less than 7% of the overall budget as contingency. SP Energy Networks is working with the potential building and cable contractors to reduce the total costs.

The costs of the network control system are still not yet known, but a realistic budget based on a PQQ and 1st round tender provides reasonable confidence this item will not use any of the overall remaining budget. The risk of exceeding the overall project budget however has increased from 20/40 to 35/40.

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.	10
1.04	Earthing with DC	High DC earth return currents.	Discontinued operation and additional cost to project to improve earthing arrangements.	1. VSC converter study required to determine the best converter arrangement for this application to reduce the level of earth return currents during normal and abnormal operation.	5

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Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
1. Technical risks					
1.06	Existing OHL integrity with DC	Suitability of existing OHL for DC operation	Flashovers across the insulators that provide structural support between the conductors and towers are likely to necessitate switching off the whole of the MVDC scheme for a period of time.	Perform study of OHL insulation requirements for designed DC voltage, visually inspect insulators on existing line and replace if necessary. 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.	30
2.04	Easements/ wayleaves	Inability to obtain a wayleave / easement for the parallel subsea AC standby circuit.	Lack of wayleave / easement for crucial mitigation measure delays entire innovative demonstration project.	Perform thorough pre-engineering studies before defining the detailed cable route and liaise closely with owners and planning authorities.	25
2.06	Damaged equipment	Equipment arrive on site are damaged due to improper packaging and shipment	Significant effect on delivery time and project programme	1- Ensure proper packaging and shipment with supplier 2- include appropriate penalties in terms and conditions to protect the project against damage or late delivery of the products	8

Risk No.	Issue	Risk Description	Potential Impact	Control & Contingency Measures	Overall Risk (2-40)
2. Procurement, manufacturing and installation risks					
2.08	Delay in delivery of converters	Delay in delivery of the MVDC equipment	The overall impact on timely delivery of the SDRCs and work in other work packages	1-Considering contingency time for production of the converters 2- Effective monitoring of the manufacturing process and define set dates for factory acceptance tests at time of contract 3- Include appropriate penalties in terms and conditions to protect the project against damage or late delivery of the products	8
2.09	Most suitable MVDC supplier is not selected	Required Project/Supplier development work and MVDC - Link operation cannot be achieved	MVDC link is not fit for purpose, resulting in decision to halt innovation project and/or failure to meet several SDRC project outputs.	1) Invitation to tender sent out to all suppliers identified in 2 stages of PQQ. 2) 1st stage control strategy studies completed early to inform tender evaluation 3) Leading MVDC expert part of MVDC link tender evaluation panel.	6
2.10	MVDC supplier carries out the project as a one-off for 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.	25

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.	35
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

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

Signature (2): Colin Taylor – Engineering Services Director