Engineering Justification Paper – Circuit Rating Management System				
Name of Scheme/Programme	Circuit Rating Management System			
Primary Investment Driver	Load: Increase thermal capacity and network utilisation			
Scheme reference/ mechanism or category	SPT200130 SPT200131			
Output references/type	LRT2SP2051			
Cost	£4.651m			
Delivery Year	2025			
Reporting Table	B0.7 Load Master Data B4.2a Scheme Summary B4.5 Scheme Asset Data B4.5a Scheme Asset Data			
Outputs included in RIIO T1 Business Plan	No			
Spend apportionment	**Scheme**	**T1**	**T2**	**T3**
	SPT200130/1	£0.120m	£4.531m	£0m

Issue Date	Issue No	Amendment Details
July 2019	Issue 1	First issue of document
December 2019	Issue 2	Updated monetary values, section 4 expanded, added section 6.
August 2020	Issue 3	Cost benefit analysis added; section 4.5 expanded.

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1 Introduction

The thermal rating of transmission circuits can be enhanced by applying Real-Time Thermal Rating (RTTR) systems to individual circuits or by using actual and forecast weather conditions to increase (or sometimes reduce) declared ratings. A range of research projects and trials have been undertaken by TOs and DNOs to demonstrate these techniques and technologies (e.g. see section 7 below).

In our view, these methods are now ready for implementation as part of our normal business processes. The project outlined in this justification paper proposes the development of a system to manage circuit ratings in planning and operational time scales.

This paper should be read in conjunction with Annex 21 – Strategic Investment Plan for Load which explains the interaction of this scheme with others in the load related plan.

2 Background Information

Typically, overhead lines, cables, transformers and other equipment like series reactors are assigned static ratings, often making provision for seasonal ambient temperature variation. We are proposing a system that will calculate static ratings based on equipment characteristics and construction data for use in planning studies. In operational timescales, those ratings will be supplemented by data from RTTR systems and weather information to provide enhanced circuit ratings.

Presently, seasonal rating schedules for continuous and short-time operation of SPT circuits are produced using a system based on obsolete software. This is not a sustainable position and is a further strong driver for this project.

3 Optioneering

The following long-list of options is being considered:

a)	Do nothing	The benefit of enhanced circuit ratings remains under-utilised. Different RTTR systems could be added in a less coordinated manner, but the full benefit in planning and operational timescales would not be realised. Limitations and support issues resulting from the use of obsolete software.
b)	Develop a new system	The development of a new bespoke system would increase the project risks considerably, although this may be deemed acceptable if a suitable system is not commercially available or could not be tailored to meet requirements.
c)	Purchase and install a commercially available system.	A range of RTTR equipment and systems is becoming commercially available and a suitable system may be available.

At this time, option a) has been rejected as it is our aim to maximise the utilisation of our assets where it is economical to do so, using a more sustainable software platform. We are developing the system requirements in more detail, which will be followed by engagement with potential suppliers. The project will continue to consider commercially available systems and work done in this area by

SPEN and other network companies (e.g. under NIA), with the aim of procuring a system that provides the best balance between system requirements, risk and cost.

4 Detailed Analysis

4.1 System Capabilities

The system will have the following capabilities:

a) Seasonal rating adjustment. The system must be capable of producing seasonal rating schedules, including short-time ratings, as already in use. See e.g. National Grid TGN(E) 26, Current Ratings for Overhead Lines.
b) Include pre-fault loading in the calculation of ratings.
c) Integration with existing or future RTTR systems from multiple vendors.
d) Adjustment of ratings based on day- or week-ahead weather forecasts.
e) Integration with the Energy Management System (EMS).
f) Integration with or data transfer to network analysis software (PowerFactory and IPSA+)
g) Integration with ESO data exchange mechanisms[1] .
h) A conductor and equipment library to establish ratings for future circuits.
i) The system must be designed with careful consideration of SPEN cyber-security policies, particularly where mobile communications or external servers are used by RTTR systems.
j) The reliability of the system should be consistent with the impact of a failure, at which point circuit ratings should revert to their static ratings.
k) The rating algorithms must provide enhanced ratings while not placing our assets at increased risk.
l) Allow for auditing and assurance of circuit ratings.

Not all circuits require enhanced or real-time ratings. The proposed system is flexible and will apply weather enhancements to all circuits and allow RTTR to be added to circuits as and when it is economic to do so.

4.2 Project development

The project is planned to be carried out in two stages:

Stage I – Updating and developing circuit rating schedules for all transmission circuits

> This stage includes developing/purchasing a circuit rating schedule application, which will be part of CRMS. The asset data from various existing databases will be collated and modified if required to create circuit asset maps. The circuit rating schedule application uses circuit asset maps to create rating schedule reports in the appropriate formats for planning and operational purposes. The circuit rating schedule reports will be created for the entire transmission network and include static seasonal ratings of circuits in pre- and post-fault conditions. The IT requirements for maintenance, data and circuit rating schedule update processes, documentation for “business as usual” (BaU) integration and staff training (end users) required for use of the circuit rating schedule application will be also delivered.

Stage II – CRMS development, testing and commissioning

[1] See https://www.nationalgrideso.com/codes/system-operator-transmission-owner-code?overview, STCP19-4 Commissioning and Decommissioning, STCP 04-3 Real Time Data Provision.

The functional and technical specifications of the CRMS will be developed by engaging with end-users and stakeholders within the business including the control room, Smart Grid Operation and IT. Market engagement with potential suppliers will be undertaken to understand their capabilities and to obtain expressions of interest from the market. The development of the platform will be awarded to a capable supplier through a competitive tendering process.

As explained in section 4.3, the service for provision of real time ratings of the circuits and weather conditions may be purchased from different capable suppliers. The commercial mechanism, liabilities required, and terms and conditions of this model of service provision will be also developed at this stage. For a limited number of circuits, these services will be purchased and trialled as part of tests and demonstration of CRMS.

The BaU integration activities will be undertaken throughout the project implementation by developing the necessary documentation, staff training, process guidance and ownership mechanisms.

Figure 1 shows a summary of work will be carried out at each stage.

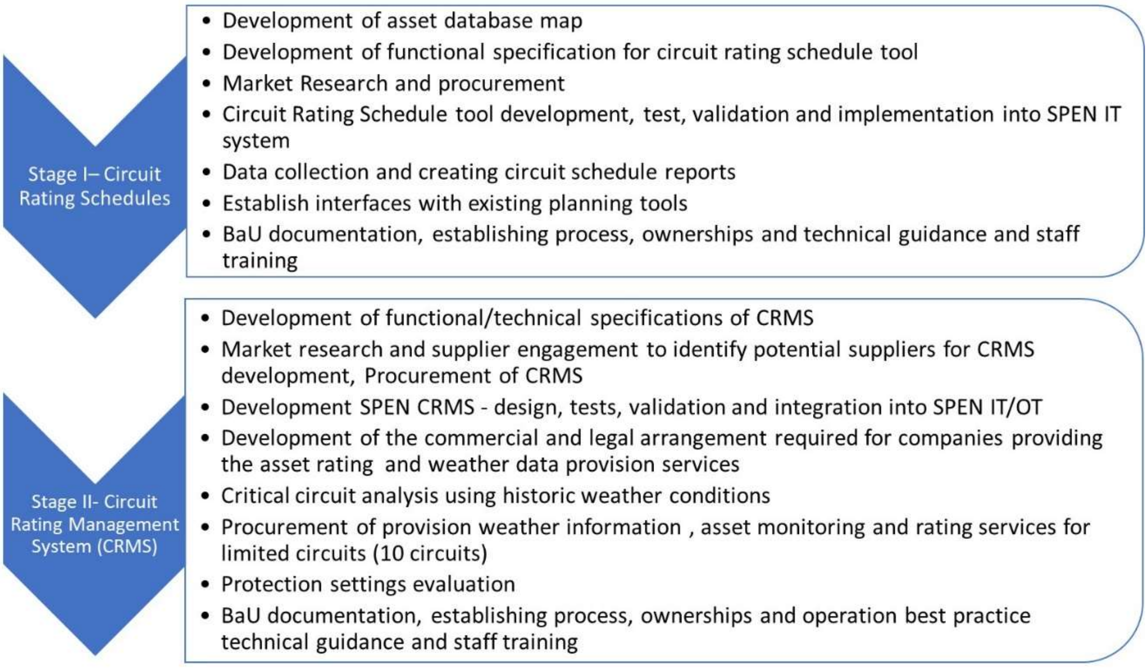

Figure 1. Project development stages.

4.3 System architecture

It is envisaged that the CRMS will be hosted on a SPEN server. However, an aim of the project is to supplement the basic circuit rating information with enhanced rating assessments directly from field devices and/or external service providers.

At a high level, two models are possible:

1. The rating of individual circuits is procured as a service (see Figure 2). E.g. external service providers install monitoring devices on a circuit, which communicate independently with the

provider. The provider then carries out an assessment of the circuit rating, which is then provided to the SPEN CRMS via the internet. If the rating is not received or is deemed infeasible, the CRMS reverts to the static rating for the circuit. This model has the advantage that the service provider is responsible for communication with field devices and maintenance of the entire rating assessment platform. It may also make it easier to switch between service providers in future. A significant disadvantage would be the risk of disruption of the service if e.g. the provider ceases trading.

2. All rating monitoring equipment and rating calculation software is owned by SPEN (see Figure 3). E.g. a thermal monitoring device installed on a cable communicates directly with a SPEN server where an assessment of the rating is made. With this approach, all aspects of the system would be under SPEN control and therefore less susceptible to disruptions. The disadvantage is that SPEN may have to host a variety of computational modules and would be responsible for providing suitable communications. This approach could be problematic for services that rely e.g. on complex weather models that could not easily or cost-effectively be hosted by SPEN.

It is likely that a hybrid approach will be required, where the model is selected based on the type of service, it's complexity, cost and the commercial terms and conditions of service contracts.

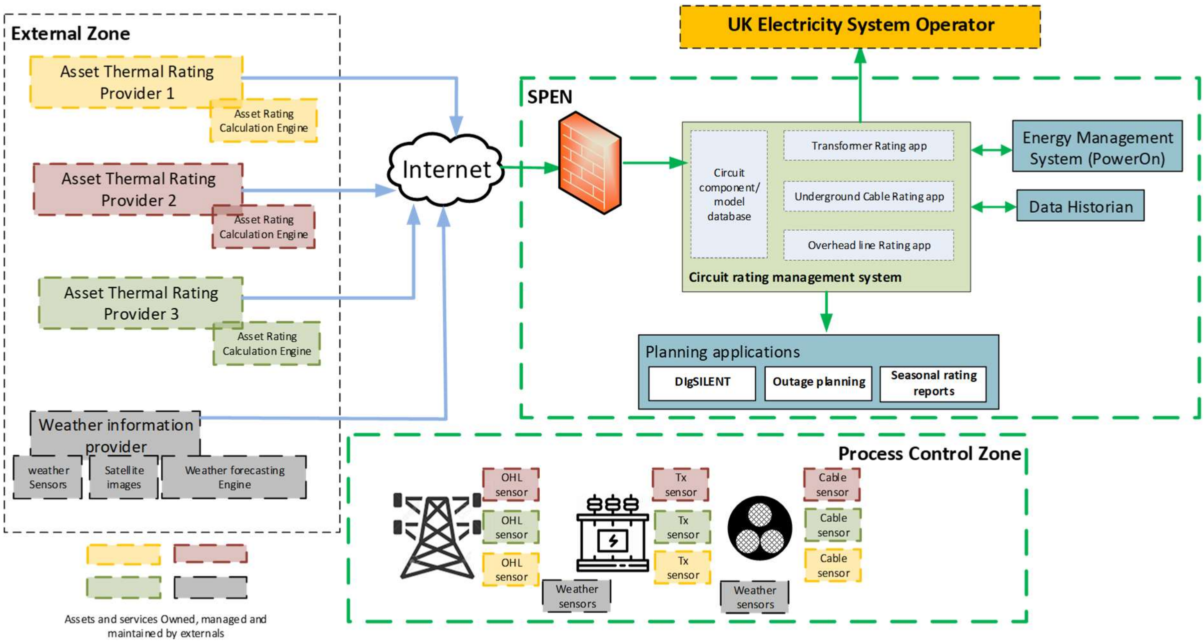

Figure 2. External RTTR (ratings calculated externally by provider).

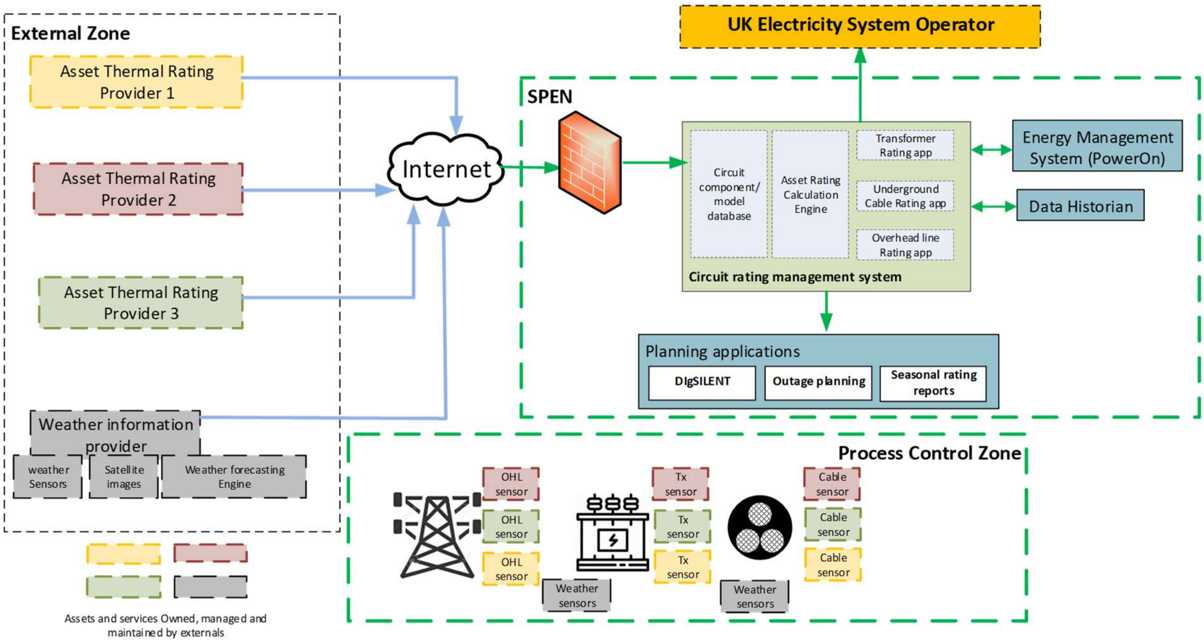

Figure 3. Internal RTTR (ratings calculated on SPEN-based system).

4.4 Losses

Increased network utilisation will also lead to an increase in transmission system losses. At this time, it is very difficult to make a reasonable estimate of the impact that the CRMS is likely to have. However, the cost of the additional losses will be outweighed by the operational cost savings that will be made possible by the system.

4.5 Cost Benefit Analysis

We have carried out two studies to demonstrate how the CRMS will help to reduce network constraints. The first study considers constraints that arise from construction outages and the second evaluates the impact that CRMS will have on a network boundary.

4.5.1 Assumptions

The following assumptions have been made in the analysis:

1. The CRMS circuit rating uplift has the distribution shown in Figure 4, i.e. 28% of the time, there is no uplift; for 63% of the time it is less than 5%, etc. Uplifts above 10% are rare and occur in less than 5.4% of the time. The maximum increase applied was 15%. The distribution in Figure 4 is based on rating increases that have been demonstrated for circuits in the Strathaven – Harker corridor, using meteorological data[2]. For the analysis, a time-series of uplift data was used directly, rather than sampling from the distribution in Figure 4.
2. A sensitivity case, where only 50% of the rating increase is available, is considered. E.g. where the 100% case applies a rating increase of 5%, only 2.5% is applied, etc. No uplift above 7.5% was therefore applied in the analysis for this sensitivity.
3. The analysis considers only the weather forecast-based rating uplift. Other system benefits, e.g. additional uplift from RTTR inputs have been ignored.

[2] National Grid Technical Report TR(T)273, Analysis of Overhead Line Thermal Ratings Using Meteorological Data, Issue 1, March 1997.

4. Rating uplift has been correlated on a month-by-month basis to capture seasonal trends. However, any correlation between increased power transfers and increased ratings due to favourable weather conditions, have been ignored.
5. A fixed cost of £65/MWh has been assumed for constraints.
6. It has been assumed that the CRMS will be modernised in 2034 at a cost of £1.0m.

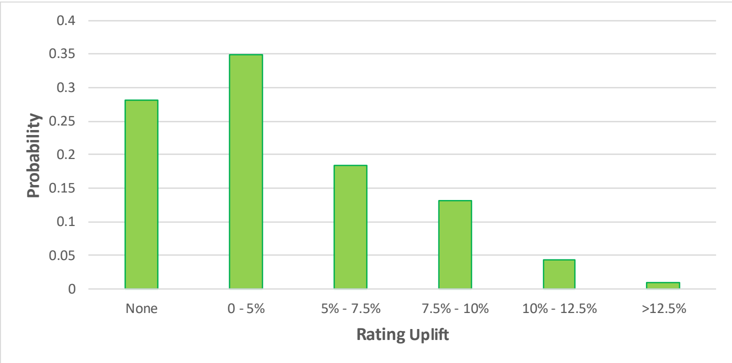

Figure 4. Assumed circuit rating uplift.

4.5.2 Case Study: Windyhill 275kV Switchgear Replacement

In our RIIO-T2 business plan, we have included a project to replace the switchgear at Windyhill 275 kV, as discussed in EJP_SPT_SPNLT2033. As part of that project, we considered the constraints that would arise from the network outages associated with different build options for the new substation equipment. Although the final economic analysis was carried out by the ESO, our own constraint modelling can be used as a case study to show how the CRMS can be used to reduce construction outages.

This case study considers the total constraint cost associated with construction outages for the AIS option for replacing the switchgear at Windyhill 275 kV. Table 1 shows the constraint costs calculated by the ESO using scenario data from FES 2019. The SPEN analysis is based on FES 2018 data, but it can be seen that there is reasonable agreement with the ESO data and sufficient to demonstrate the impact of the CRMS. The SPEN results in Table 1 show how the constraint costs reduce when 50% and 100% of the assumed rating uplift is applied to the affected circuits.

Table 1. Windyhill 275 kV estimated constraint costs for AIS option.

Analysis	Boundary Uplift	Total Constraint Cost by Scenario (£m)			
		Steady Progression	Consumer Evolution	Community Renewables	Two Degrees
ESO FES 2019	0	27.5	17.9	21.6	50.8
SPEN FES 2018	0	22.8	22.0	31.1	44.6
	50%	18.7	18.4	26.2	37.3
	100%	15.5	15.6	22.2	31.4

Table 2 shows the constraint cost savings that could be obtained if the CRMS were fully in service during the Windyhill 275 kV works. It can be seen that even when only a reduced rating uplift of 50% is used, the CRMS would recover a significant portion (around 75%) of its total cost under the scenario with the lowest constraints (Consumer Evolution). Using the full expected rating uplift, the cost of the CRMS is lower than the constraint costs it saves on the Windyhill 275 kV project for all scenarios.

Table 2. Constraint cost savings from CRMS.

	Constraint Cost Savings by Scenario (£m)			
Boundary Uplift	**Steady Progression**	**Consumer Evolution**	**Community Renewables**	**Two Degrees**
50%	4.1	3.5	4.9	7.3
100%	7.3	6.4	8.9	13.2

4.5.3 Cost Benefit Analysis: Boundary B5

To demonstrate the impact of the CRMS on boundary constraints, estimates were made of the constraints associated with B5, from 2024 when the scheme is expected to be operational, to 2044. It has been assumed that the constraint costs from 2031 to 2044 are equal to the average of the costs in 2029 and 2030. By that time, a number of NOA boundary upgrades are assumed to have been completed and the estimated constraint volumes are in the order of £1m per year.

Note that our analysis includes only constraint costs savings (i.e. avoided balancing market costs). The impact on e.g. carbon savings has not been considered.

The results in Table 3 show the overall cost savings made by the CRMS for each of the FES 2020 scenarios. For each scenario a "do nothing" baseline was established against which the impact of the CRMS could be determined for each scenario. Therefore this option has zero NPV in Table 3.

Table 3. Constraint costs savings from CRMS by scenario.

			NPVs based on Payback periods (£m)						
Option No.	**Desc. Of Option**	**Total Forecast Expenditure** *(£m)*	**Total NPV**	**Delta** *(Option to baseline)*	**10 Years**	**20 Years**	**30 Years**	**45 Years**	**Total NPV** *(Incl. Monetised Risk)*
Baseline	**Do Nothing**	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
1	**CRMS FES = Steady Progression**	**-£ 5.65**	**£ 33.92**	**£ 33.92**	**£ 8.60**	**£ 18.57**	**£ 26.43**	**£ 32.66**	**£ 33.92**
2	**CRMS FES = System Transformation**	**-£ 5.65**	**£ 10.69**	**£ 10.69**	**£ 2.80**	**£ 5.95**	**£ 8.37**	**£ 10.29**	**£ 10.69**
3	**CRMS FES = Consumer Transformation**	**-£ 5.65**	**£ 20.01**	**£ 20.01**	**£ 3.63**	**£ 9.70**	**£ 14.93**	**£ 19.09**	**£ 20.01**
4	**CRMS FES = Leading the Way**	**-£ 5.65**	**£ 31.30**	**£ 31.30**	**£ 3.43**	**£ 13.18**	**£ 22.33**	**£ 29.63**	**£ 31.30**

The CRMS leads to constraint cost savings in excess of its own cost in all scenarios. The lowest NPV is £10.69 for System Transformation. We have considered this scenario more closely, as shown in Table 4. This table shows total costs for "Do Nothing" and two CRMS options. Option 1 is the same as Option 2 in Table 3 (note that the total NPV in Table 3 matches the NPV Delta in Table 4) and assumes that the full assumed CRMS rating uplift can be applied to circuits limiting the boundary transfer. Option 2 demonstrates the impact if only 50% of the CRMS rating increase is available at any time. This increases the constraint volume and therefore reduces the NPV of this option. However, the NPV remains higher than for the "Do Nothing" case. I.e. even if the CRMS performance is significantly lower than estimated, the system has a better NPV than the "Do Nothing" option.

Table 4. CBA results for CRMS using half and full rating uplift (System Transformation scenario).

Option No.	Desc. Of Option	Total Forecast Expenditure *(£m)*	NPVs based on Payback periods (£m): Total NPV	Delta *(Option to baseline)*	10 Years	20 Years	30 Years	45 Years	Total NPV *(Incl. Monetised Risk)*
Baseline	**Do Nothing**	£ -	-£ 31.58	£ -	-£ 8.95	-£ 18.18	-£ 25.06	-£ 30.52	-£ 31.58
1	**CRMS 100%**	-£ 5.65	-£ 20.88	£ 10.69	-£ 6.15	-£ 12.23	-£ 16.69	-£ 20.23	-£ 20.88
2	**CRMS 50%**	-£ 5.65	-£ 25.72	£ 5.86	-£ 7.72	-£ 15.19	-£ 20.62	-£ 24.93	-£ 25.72

4.5.4 Summary

The two studies presented above demonstrate that the CRMS enables significant constraint cost savings during network outages and in relation to boundary constraints. Both studies show cost savings substantially in excess of the cost of the CRMS for all FES scenarios. This remains the case, even when the sensitivity is considered where the CRMS only achieves half of the assumed circuit rating uplift. The wider system benefit of the CRMS will be excess of that demonstrated by the two case studies and it can be concluded that the CRMS has cost benefits substantially in excess of its cost.

5 Conclusion

Our proposed circuit rating management system will provide enhanced circuit ratings in planning and operational timescales. This will improve the utilisation of our assets and enhance the capability of our network to transmit more renewable energy. This is confirmed by two case studies, both showing that the CRMS will provide significant cost benefits, i.e. a significant positive NPV relative to the existing position (i.e. "do nothing").

6 Future Pathways – Net Zero

Primary Economic Driver

The primary driver for this investment is to improve network utilisation. The project aims to maximise circuit ratings as far as possible without subjecting our assets to excessive risk. Depending on weather conditions, this will enable higher output from renewable generation.

Payback Periods

The use of enhanced or real-time rating will lead to reductions in network constraints. Complex analysis is required to estimate the potential constraint savings. However, the cost of this project is modest compared to the cost of constraints in the SPT area and a rapid payback is expected.

Pathways and End Points

This solution is justified in all Future Energy Scenarios. We anticipate that improved management of circuit ratings will lead to enduring benefits, regardless of the future pathway.

Asset Stranding Risks

We do not consider there to be a risk of asset stranding.

Sensitivity to Carbon Prices

This scheme is not sensitive to carbon price changes.

Future Asset Utilisation

We anticipate that improved management of circuit ratings will lead to enduring benefits and therefore ongoing use of any assets provided under this project.

Whole Systems Benefits

This project enables system operation with very high levels of renewable generation, thus contributing directly towards the achievement of Net Zero.

7 Supporting Documentation

1. SPEN 132 kV RTTR project North Wales http://www.smarternetworks.org/project/spt1001
2. SPEN 33 kV RTTR project St Andrews https://www.spenergynetworks.co.uk/userfiles/file/Dynamic%20thermal%20rating%20of%20assets%20Cupar%20and%20St%20Andrews%20RTTR27.10.pdf
3. SPEN Offline Planning Tool for Dynamic Thermal Rating http://www.smarternetworks.org/project/ifi1001
4. SPEN Transition to Dynamic Cable Rating Operation http://www.smarternetworks.org/project/nia_spen_032
5. SPEN Enhanced Weather Modelling for Dynamic Line Rating http://www.smarternetworks.org/project/prj_1128
6. SSEN Dynamic Line Rating CAT1 http://www.smarternetworks.org/project/nia_shet_0004
7. NGET Advanced Line Rating Analysis (ALiRA) http://www.smarternetworks.org/project/nia_ngto014
8. NGET Dynamic Ratings for improved Operational Performance (DROP) http://www.smarternetworks.org/project/nia_nget0047
9. NGET & SPEN Enhanced Weather Modelling for Dynamic Line Rating (DLR) http://www.smarternetworks.org/project/nia_nget0105
10. NGET Overload Rotation to Increase Capacity of Transmission Boundaries http://www.smarternetworks.org/project/nia_ngto030
11. Rating systems developed by National Grid and Oxford Computer Consultants, like TRALC, GLOIN, ROCIT, CTM. See e.g. https://www.oxfordcc.co.uk/custom-software/overhead-line-rating/