Running Cool

NIA Closedown Report

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1. Executive Summary

Full Active Network Management (ANM) systems are implemented in areas where multiple complex constraints affect a number of customers over a long time period. ANM systems will typically curtail customers who have agreed to Flexible or Curtailable terms under intact network conditions in anticipation of the next worst circuit fault to ensure asset loads remain within post-fault ratings in the event of that fault occurring. This strategy of pre-event curtailment ensures the network remains secure but does mean that curtailment is enacted even if an event doesn't occur. Where networks are subject to significant levels of curtailment, this can be a significant barrier to new, renewable generation connecting. In addition, following implementation of OFGEM's Access Significant Code Review in March 2023, Distribution Network Operators (DNOs) are now required to issue new Curtailable[1] customers with limits on the curtailment they are subjected to, and are liable to compensate these customers should limits be breached.

Network Innovation Allowance (NIA) project 'Running Cool' sought to challenge current curtailment arrangements by creating an enhanced post fault capability for overhead lines (OHLs) and a new ANM architecture which can help to avoid curtailment. The project was delivered in collaboration with Nortech Management Limited through the following five work packages (WPs):

- WP1 Changes to ANM Control System Architecture
- WP2 Short-term Post-fault Ratings (STPFR) and Risk Assessment
- WP3 Network Use Cases
- WP4 Final Control System Architecture and Device Specification
- WP5 Cost Benefit Analysis (CBA) and Policy Amendments

The total project budget on completion was £368,382. The main findings/outputs can be summarised as follows (further detail in Section 5):

- Results of the analysis demonstrated a clear potential for capacity release and financial benefits associated with implementation of STPFR capability on OHL network on a "little but often" basis – rating uplift was generally modest but frequently available - with significant aggregate volume. The greatest uplift is produced during the cooler months of the year
- For circuits with limited available capacity, operating at the static seasonal rating, and consequently higher temperature, the implementation of STPFR method will not produce a significant potential uplift
- Functional specification for the implementation of STPFR to the existing ANM control system architecture was prepared to enable business as usual integration
- Functional specification for OHL temperature monitoring equipment was prepared to monitor conductor temperature to subsequently derive STPFRs.

Full detail on the results and learning of the project is available throughout this report and specifically in Section 5, 6 and 9. To realise the benefit of STPFR method trialled as part of the project, further developments are recommended as follows:

- Changes to the existing ANM system to enable a functionality to receive dynamic ratings
- Implementation of the required changes within NGED control environment to enable secure transfer of STPFR values along with other network measurements
- Work across NGED DSO, procurement and policy teams on the governance of STPFR methodology delivery (identification of trigger points for implementation, procuring of the monitoring equipment, policy and guidance of the installation and maintenance of the monitors, etc)

2. Project Background

There is a finite limit to the available capacity across the higher voltage distribution circuits, and several regions across the distribution licence areas are already operating towards the capacity limits. To accommodate further connections to the distribution network, without the significant costs of reinforcement, DNOs currently offer alternative managed solutions to new connections. However, this can result in a significant volume of curtailment throughout the year, impacting the customer's business case, and deterring often 'clean' generators from connecting to the distribution system.

ANM systems are being implemented to manage and curtail customers that connect in areas where multiple complex constraints affect customers over an extended period. Depending on the network operating conditions (for example system intact or n-1 contingency), OHL ratings are either pre-fault or post-fault, meaning that a significant number of these connections can be curtailed on a precautionary basis under intact network conditions, in anticipation of the next 'worst circuit' fault to keep assets within defined ratings. This arrangement can ultimately lead to customers being curtailed despite the absence of faults. Moreover, the increased level of curtailment can lead to generators being unable to justify the business case, resulting in a reduced volume of new generation.

Under previous regulatory arrangements, generators triggering network reinforcement in the upstream, higher voltage level would be required to contribute to the cost on a pro-rata basis depending on the (static) capacity utilised. However, a reform to access rights in April 2023, implemented by Ofgem through the Access Significant Code Review means that generators are only required to contribute towards reinforcement at the same voltage level as the point of connection, with the removal of the charge for wider network reinforcement being subject to the High Cost Project Threshold of £200/kW. Instead, any compulsory reinforcement at the voltage level above will be borne by the DNO. It will be the responsibility of the DNO to ensure that there is sufficient capacity for all generation connection applications.

The aim of this project was to challenge current curtailment arrangements by creating a new post fault capability for OHL and a new ANM architecture which could help to avoid curtailment. An improved system of short-term dynamic OHL ratings (informed by real-time conductor temperatures) and a new corresponding ANM control system architecture are the key outputs of this work.

3. Scope and Objectives

Scope

This project sought to challenge current ANM curtailment arrangements by creating a new post fault capability for OHLs and a new ANM architecture which will help to avoid curtailment. An improved system of short term dynamic OHL ratings (informed by real-time conductor temperatures) and a new corresponding ANM control system architecture are the key outputs of this work. By improving the overall capacity of the distribution network NGED can look to accommodate more clean embedded generation connections, which would lead to a reduction in the overall carbon intensity of energy delivered to customers and thereby help to deliver and achieve 'Decarbonisation and Net Zero' – a priority area in NGED Innovation Strategy.

Objectives

This project aimed to integrate a STPFR (derived from real-time conductor temperature measurements) into ANM systems in order to create a new post fault capability for OHLs. The key objectives of the projects are shown in Table 3-1 below. Full detail on how the set objectives were met are provided throughout this document and specifically in Sections 5, 6 and 9.

Table 3-1: Status of project objectives

Objective	Status
Demonstrate what benefits can be realised by the application of OHL STPFRs in ANM	✓
Develop all required documentation to ensure safe integration of new capability into ANM	✓

4. Success Criteria

The project successfully met the criteria specified in the original "NIA Project Registration and Project Eligibility Assessment (PEA) document" dated June 2022. The success criteria for the project are summarised in Table 4-1 and further details explaining how these criteria were met can be found in Section 6.

Table 4-1: Status of project objectives

Success Criteria	Status
The benefits that can be realised by the application of OHL short-term post-fault ratings in ANM are quantified and documented	✓
A specification document for the ANM system incorporating new functionality	✓
Specification documents for relevant monitoring devices is finalised and fit for purpose	✓
Relevant policies reviewed and recommendations for amendments are documented and approved	✓

5. Details of the Work Carried Out

The delivery of Running Cool was split into five separate Work Packages (WPs) as detailed in the PEA and summarised in table 5-1. Further details on the individual WPs are provided within the following sections of this report.

Table 5-1 Running Cool Work Packages

Ref	Description	Delivered by
WP1	Changes to ANM Control System Architecture	Nortech in collaboration with NGED
WP2	Short-term Post-fault Ratings and Risk Assessment	Nortech in collaboration with NGED
WP3	Network Use Cases	Nortech in collaboration with NGED
WP4	Final Control System Architecture and Device Specification	Nortech in collaboration with NGED
WP5	Cost Benefit Analysis and Policy Amendments	Nortech in collaboration with NGED

5.1 Work Package 1: Changes to ANM Control System Architecture

This work package focused on providing a functional specification for the implementation of STPFRs to the existing ANM control system architecture.

This work package built on the following:

- A review of the existing ANM system architecture to understand the requirements for the implementation of STPFR.
- Provide options for implementing necessary changes to the ANM system architecture to support the use of STPFRs.
- An assessment of failover arrangements of the ANM system in the event that conductor temperature information becomes unavailable.

The proposed functional specification and solution architecture is based on an ANM system implementation that is capable of receiving and utilising real time STPFR.

5.1.1 Implementation Strategies

Three strategies are available for passing the STPFR value from the source STPFR system to the ANM.

- The STPFR system can send the STPFR value(s) directly to the NGED PowerOn. These are then included in the PowerOn to ANM ICCP transfer set, in conjunction with the majority of other ANM signals.

- The STPFR system can send the STPFR value(s) via DNP3 directly to the ANM system FEP (Front End Processor).

- The STPFR system can send the STPFR value(s) via a RESTful API directly into the ANM database.

The preferred method of implementation is by using the STPFR system to send the value(s) directly to the NGED PowerOn. This avoids the creation of multiple interfaces to the ANM system (which in turn has an undesirable IT maintenance burden).

5.1.2 Architecture Implementation

Figure 5-1 illustrates the proposed system architecture between NGED PowerOn and the ANM system.

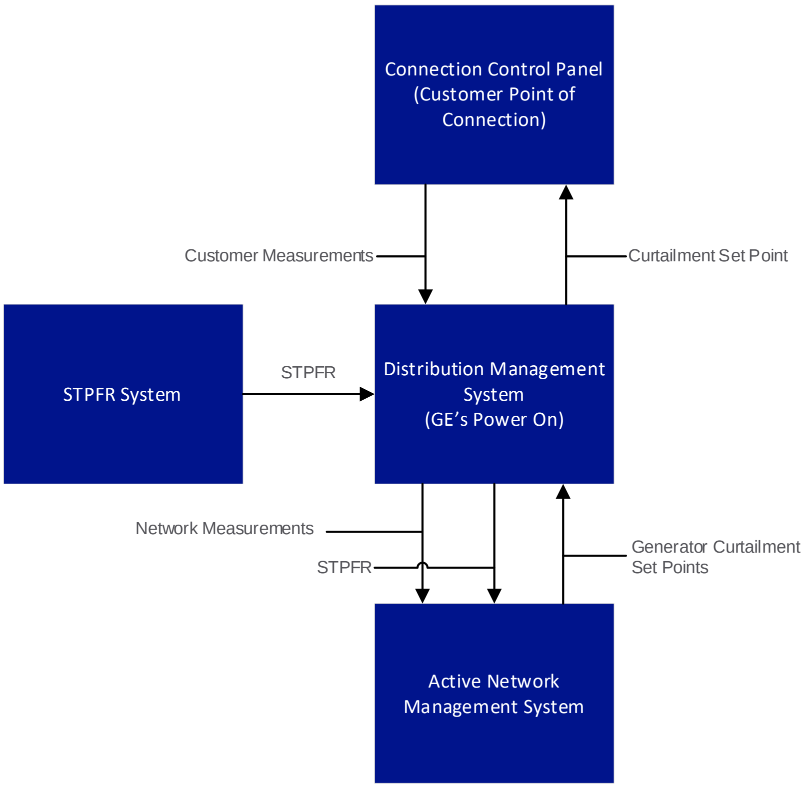


Figure 5-1: ANM System Architecture

For further information, please refer to Work Package 1.2 (ANM System Architecture Changes Technical Specification & Implementation that can be found on NGED Innovation webpage: National Grid - Running Cool).

5.2 Work Package 2: Short-Term Post-Fault Rating and Risk Assessment

This work package provided a functional specification for STPFRs, building upon the learnings of a previous NGED NIA project, 'Overhead Line Power Pointer' [1], where OHL smart sensors capable of self-powered operation, capture real-time current, conductor temperature, and directional power flow were tested.

The STPFR of an OHL exploits the thermal capacity of the conductor material (such as aluminium, aluminium alloy or copper). The calculation of the adiabatic rating, based on CIGRE Technical Brochure 601 [2], is not dependent on the measurements of other heat transfer mechanisms (such as convective cooling, solar heating, and radiative heating/cooling). The conductor temperature measurement is the only parameter required to be monitored in real-time to provide a rating to cover short-term (up to 10 minutes) post-fault loads. A 10-minute rating was selected to allow ANM systems to take "post-event" actions since ANM reaction and enaction times have been shown to be as long as 10 minutes. A full working out of the STPFR methodology can be found in Work Package 2 (Short-Term Post Fault Rating Technical Specification and Risk Assessment that can be accessed on NGED Innovation webpage: National Grid - Running Cool).

Work Package 2 conducted a Failure Modes and Effects Analysis (FMEA) on the STPFR solution architecture in order to produce a comprehensive risk assessment of its implementation. This is a systematic method to evaluate each process and component in the system to identify how it may fail and what mitigations can be implemented to manage the failure modes. The complete FMEA table is available in Work Package 2 (Short-Term Post Fault Rating Technical Specification and Risk Assessment) which is available on NGED Innovation webpage: National Grid - Running Cool.

5.3 Work Package 3: Network Use Cases

This work package presented the methodology and results for the assessment of network use cases and the quantified benefits realised by the application of STPFRs both in isolation and when integrated with ANM. Table 5-2 indicates the location where the data was collected from for further analysis:

Table 5-1 2 NGED network sites with SN2.0 installations

Site/ Circuit	License Area	Number of Installations	Conductor Type
K-Line - ALVE 305 (NOMO)	South West	6	175 mm2 Lynx, ACSR
ALVE 205 (GALS)	South West	4	175 mm^2 Lynx, ACSR
Staythorpe	East Midlands	2	175 mm^2 Lynx, ACSR
Melton Mowbray	East Midlands	2	175 mm^2 Lynx, ACSR
SPEN Boundary	South Wales	4	175 mm^2 Lynx, ACSR
Pembroke	South Wales	1	175 mm^2 Lynx, ACSR
Rame	South West	2	175 mm^2 Lynx, ACSR
Totnes	South West	1	175 mm^2 Lynx, ACSR

SN2.0 locations on K-Line, a 132kV circuit in Cornwall/ Devon, and from Running Cool sites was used to analyse the increase in available energy capacity when a STPFR is implemented. In doing

so, the increase in available capacity has been assessed and compared against the static post-fault rating.

Results indicate that circuits rated at 50°C using 175 mm2 Lynx conductor have demonstrated the potential yearly uplift in capacity of OHL distribution circuits using a STPFR to be approximately 6,842 MWh on average when compared to the static post-fault rating. Similarly, circuits rated at 75°C using a 175 mm2 Lynx conductor can offer 2,961 MWh of capacity uplift on average.

The greatest uplift is produced during the cooler months of the year as a result of lower ambient temperatures cooling the conductor while it operates at an equivalent load. For circuits with limited available capacity, operating at the static seasonal rating, and consequently higher temperatures, the implementation of STPFRs will not produce a significant potential uplift. For circuits where this is the case, the implementation of an STPFR must be assessed further to confirm where the benefit could be derived.

A selection of SN2.0 trial sites that are subject to or considered for ANM have undergone a curtailment analysis to quantify the reduction in curtailment to new customers when using a STPFR compared to the static post-fault rating. Using an NGED curtailment analysis tool, results have shown that STPFRs present a reduction in curtailment of approximately 1% over the static post-fault rating. While the difference in curtailment reduction appears small between the static post-fault rating and the STPFR, the DNOs exposure to risk is preserved when considering the exceedance and potential for conductor temperature excursions above the maximum design temperature.

On this basis, STPFRs represent a solution for the DNO to unlock significant aggregated latent capacity headroom (“little but often” benefit) without a change to the DNOs risk posture when compared to static post-fault ratings which have a 9% exceedance value. The deterministic nature of STPFRs and the 10-minute interval for ANM response does not increase any currently accepted risk of exceedance. However, the preserved level of risk exceedance relies on the ANM system’s ability to react within the 10-minute STPFR window.

When combined with ANM or flexibility systems, STPFRs have the potential to significantly reduce curtailment for customers connected under curtailable or flexible terms. A reduction in curtailment for customers on Curtailable Connection terms will reduce the likelihood of curtailment limits being breached, thereby reducing the need for the procurement of Flexibility Services and, where applicable, extending the time period over which Flexibility is cost advantageous over physical asset reinforcement. Reduced curtailment also provides customer benefit (in the form of revenue) by increasing the amount of energy exported.

5.4 5.4 Work Package 4: Final Control System Architecture and Device Specification

This Work Package 4.1 built on the following:

- A review of the existing ANM system architecture.
- The considered approach for implementing necessary changes to the ANM system architecture to support the use of STPFRs (including interoperability with multiple ANM system providers and future-proofing of the solution).
- An assessment of failover arrangements of the ANM system in the event that conductor temperature information becomes unavailable.

The proposed functional specification and solution architecture is based on an ANM system implementation that is capable of receiving and utilising real time STPFR.

Based on feedback from NGED ANM providers and their consideration of the incorporation of Dynamic Line Ratings (DLRs) within their ANM solution, this has been used to inform the overall solution architecture (encompassing iHost and PowerOn) and updated for consistency.

Moreover, the handling of STPFRs has been considered and future-proofed by architecting the solution such that STPFRs are transferred from iHost to PowerOn (rather than from iHost directly to other ANM systems). This modular architecture means that NGED can make STPFRs available to existing ANM systems (ZIV and SGS) as well as to any future ANM systems (whether developed within the PowerOn environment itself or as a satellite system to PowerOn).

Work Package 4.2 (Retrofit OHL Temperature Monitoring Equipment Engineering Specification) provides the specification for equipment which can be retrofitted to OHL systems in order to monitor conductor temperature and that will be used to derive STPFRs for OHL conductors. Please refer to Work Package 4.2 for the complete Engineering Specification (available on NGED Innovation webpage: National Grid - Running Cool).

5.6 Work Package 5: Cost Benefit Analysis and Policy Amendments

Work Package 5.1 (Cost Benefit Analysis) focused on the quantitative cost-benefit analysis and qualitative discussion of the impact of STPFRs on OHL conductor design life.

The “little but often” benefit provided by STPFRs assumes STPFRs are constantly evaluated and used to completely defer flexibility procurement. The CBA has shown that approximately 22MWh of Flexibility is required to break even with the cost of SN2.0 installation, making up a fraction of the potential yearly reduction in Flexibility procurement, which further emphasises the low threshold for a net positive business case across a range of circuits.

As a further example, K-Line sites with multiple units installed along the circuit have shown that heavily loaded circuits with limited headroom could still offer a potential yearly reduction in Flexibility procurement of 341 MWh, or a £102,300 saving. Moreover, results for prospective ANM locations have shown an average potential reduction in Flexibility procurement of £96,483, equivalent to 322 MWh, with only a single SN2.0 installed.

The net positive business case for SN2.0’s provides more options for DNOs to manage new generation connections on the network and reduce the amount of Flexibility procured or any additional curtailment penalties. There is also an opportunity to procure cheaper temperature monitoring devices delivering even bigger saving. The Functional specification for OHL temperature monitoring equipment prepared as part of WP4 can support the procurement of alternatives to SN2.0 if required.

The utilisation of additional post-fault capacity headroom in circuits, beyond conventional pre-event seasonal static ratings, has the potential to allow OHLs to be operated much closer to design temperatures than has previously been possible. The 9% exceedance risk used by static post-fault ratings is not increased when using STPFRs due to the deterministic nature of the STPFR calculation and the 10-minute window for ANM system response during an unplanned fault event.

Work Package 5.2 (Policy Amendments) reviews relevant NGED policies and provides recommendations for amendments (available upon request).

6 Performance Compared to Original Aims, Objectives and Success Criteria

Running Cool successfully delivered against all the original aims, objectives and success criteria that were set out at the start of the project. Table 6-1 and table 6-2 provide further detail.

Table 6-1: Performance compared to project objectives

Objective	Status	Performance
Demonstrate what benefits can be realised by the application of OHL STPFR in ANM	✔	Network use case and CBA work packages demonstrated potential capacity release and financial benefits that OHL STPFR can provide when integrated within ANM system. Results indicated that 132kV OHL circuits rates at 50°C using 175 mm2 Lynx conductor can provide potential yearly uplift of approximately 6,842 MWh on average when compared to the static post-fault rating. Similarly, circuits rated at 75°C using a 175 mm2 Lynx conductor can offer 2,961 MWh of capacity uplift on average. The greatest uplift is produced during the cooler months of the year. For circuits with limited available capacity, operating at the static seasonal rating, and consequently higher temperatures, the implementation of STPFRs will not produce a significant potential uplift. For circuits where this is the case, the implementation of an STPFR must be assessed further.
Develop all required documentation to ensure safe integration of new capability into ANM	✔	As specified in Section5, the following documentation was developed as part of the project (also available on NGED Innovation webpage: National Grid - Running Cool): - Functional specification for STPFR of an OHL that exploits thermal capacity of the conductor material. - Functional specification for the implementation of STPFR to the existing ANM control system architecture. The proposed functional specification and solution architecture is based on ANM system implementation that is capable of receiving and utilising real time STPFR - Failure Modes and Effects Analysis to evaluate each process and component in the system (when using STPFR) to identify how it may fail and what mitigation actions can be implemented to manage failure modes - Functional specification for OHL temperature monitoring equipment in order to monitor conductor temperature to subsequently derive STPFR - Recommendations for Policy amendments, specifically SD8A/2 “Relating to Revision of OHL Ratings” and Draft ST “Relating to the Installation and Maintenance of OHL Monitoring Devices”

Full detail can be found in individual project reports available on NGED Innovation webpage:
[National Grid - Running Cool]

Table 6-2: Status of project success criteria

Success Criteria	Achieved	Performance
The benefits that can be realised by the application of OHL short-term post-fault ratings in ANM are quantified and documented	✓	Results of the network use cases analysis and CBA demonstrated a clear potential for capacity release and financial benefits associated with implementation of STPFR capability on OHL network, i.e. “little but often” benefit with significant aggregate energy volume.
A specification document for the ANM system incorporating new functionality	✓	Functional specification for the implementation of STPFR to the existing ANM control system architecture was prepared as part of the project and is available upon request. Engagement with current NGED ANM providers confirmed that existing ANM systems are capable of integrating dynamic rating within their systems.
Specification documents for relevant monitoring devices is finalised and fit for purpose	✓	Vendor agnostic functional specification for OHL temperature monitoring equipment was prepared and available upon request
Relevant policies reviewed and recommendations for amendments are documented and approved	✓	Recommendations for two relevant policy documents documented and available upon request.

7 Required Modifications to the Planned Approach during the Course of the Project

Three changes were required during the course of the project reflecting the need for additional time for equipment delivery and installation, ensuring data capture period is enough to draw reasonable conclusions and restructure of the delivery plan to align with installation schedule:

- Change request 1: to extend the project to December 2023. The need for project extension was due to delay in equipment delivery, complexities around outage arrangement for equipment installations in winter /spring months. Project was restructured to align Running Cool installation dates and existing NGED major project outage schedule to avoid outage cancellations. This arrangement ultimately allowed for the project budget saving.

- Change request 2: to extend the project to March 2024. During the course of the project there has been a communications issue (more detail in Section 9) which caused the loss of data in two sites. The decision was made to extend the project by another three months to ensure there is sufficient data captured to carry on with the analysis.

- Change request 3: to restructure the project plan. The delivery dates for WP5 deliverables were changed to ensure policy recommendations are finalised after all the project activities were carried out.

All change requests were managed according to the NGED governance process with no impact on budget or quality.

8 Project Costs

Table below outlines the spend on the project against the project budget.

Table 8-1: Overall Project Spend

Activity	Budget	Actual	Variance (%)
Project and Programme Management	£80,272	£87,131	8.5
Network Services Install/Labour	£12,570	£5,651	-55
Equipment (10 sets of Smart Navigators)	£34,150	£34,150	0
Nortech Consultancy services	£200,000	£221,450	10.7
Purchase of power system model to enable analysis	£2,000	-	-100
Contingency	£32,899.20	Included in actuals £21,450	Remaining £11,449
Partner Contribution	£20,000	£20,000	0
Totals	**£381,891.20**	**£368,382**	

Comments around variance:

- Project and Programme management budget was increased to cover project management time associated with project extension
- NGED network services budget was optimised by arranging installation of the equipment on the same day and/or during the outage period arranged for wider operational activities
- Nortech consultancy fee was increased due to project timeline extension to cover additional project management support for the extended period. Part of the contingency was used to cover additional expense
- Purchase of the power system model was mitigated by alternative provisions and saved the project £2,000.

9 Lessons Learnt for Future Projects and Outcomes

Table 9 details the key learnings that were generated during the course of the project.

Table 9-1: Lessons learnt

Ref	Area	Description
1	ANM system	NGED have different ANM arrangements depending on a licence area. Implementation of the STPFR capability will require all vendors to be able to accommodate acceptance of dynamic ratings within their power system analysis and decision making.
2	ANM system	The ANM system would require the rating values to be sent to the ANM system every 5 seconds or greater. The ANM system requires the rating to be in either Amps or MVA.
3	Equipment	Equipment installation required coordination with multiple teams across the business and the collaborative partner (Nortech) who was responsible for equipment delivery. The monitoring equipment was shipped from Germany and was held at customs which was not expected. Due to this delay the project team had to cancel an outage in Rame (South West) that was arranged for the 1st Running Cool installation and led to the project extension. During the course of the project, a framework agreement was signed to ensure smooth delivery of Smart Navigators (SN2.0) when required, however, further consideration should be given to the contractual arrangements with other vendors if/when STPFR capability is rolled out across the business.
4	Equipment	Equipment used for the temperature monitoring (SN2.0) use sim card for information transfer. During the course of the project there had been a few malfunctions where sims stopped communicating with iHost which led to the loss of data for a period (up to 3 months). If STPFR capability is implemented within ANM such comms failure will be critical; therefore further consideration should be given into failover arrangements by ANM providers and alternative comms solution.
5	Equipment	Standard Technique for installation of SN2.0 on OHL[1] was not detailed enough for 132kV OHLs. This has caused minor confusion across operation staff. As a result, feedback from operation personnel was sought and standard technique updated (in draft).
6	WP1	There are multiple ways of passing STPFR values from the system that would derive the values to the ANM. The preferred implementation method is for STPFR system to send values directly to NGED Control System (PowerOn). This arrangement will eliminate a need for multiple interfaces with the ANM system. It will reduce undesirable IT maintenance burden and future proof the system if/when ANM functionality is taken in house (i.e. implemented within PowerOn).

[1] Developed as part of previous NIA project – OHL Power Pointer

Ref	Area	Description
7	WP1	It is expected that the STPFR will be delivered to ANM in the same ICCP transfer as the network measurements. Additionally, the ANM system will have access to a set of static ratings that are used by default if the STPFR is unavailable via the ICCP transfer set.
8	WP2	The calculation of STPFR, based on CIGRE Technical Brochure 601, is not dependent on convective cooling, solar heating and radiative heating/cooling. The conductor temperature measurement is the only parameter required to be monitored in real-time to provide a rating to cover STPF generation curtailment events.
9	WP3	The increase in available capacity when using STPFR has been assessed and compared against a static post-fault rating.
10	WP3	For 175 mm2 Lynx conductor rated at 50°C results demonstrated that the potential yearly uplift in capacity of OHL circuit using STPFR is 6,842 MWh on average when compared to the static post-fault rating. For 175 mm2 Lynx conductor rated at 75°C the results indicate potential yearly uplift in capacity of 2,961 MWh on average. The greatest uplift is produced during cooler months.
11	WP3	A common hourly uplift profile was identified by this study amongst all sites which produced the minimum uplift during peak sunlight hours and the bulk of the uplift during the evenings and mornings. This uplift profile would benefit generators that have a constant energy output irrespective of meteorological conditions. This is a result of the adiabatic methodology used to obtain the STPFR which is dominated by ambient temperature, which has a bell curve profile, and conductor load. Generators such as PV connections that have an output profile similar to the ambient temperature profile will not be capable of reaping the full benefits of STPFRs.
12	WP3	The benefits of the STPFR capability can only be realised under a condition when uplift is present at the time of a circuit being thermally constrained.
13	WP3	The results of this study demonstrate that the implementation of STPFR offers a “little but often” benefit with significant aggregate energy volume that will further unlock latent capacity within the distribution network.
14	WP4	SN2.0 devices used during this study for live temperature measurements have been proven efficient. Along with temperature monitoring, SN2.0 provide visibility of real-time voltage, current and directional power flow which is not required for STPFR capability. There is an opportunity to explore alternative technologies with a sole purpose of temperature monitoring if they are proven to be a cheaper option. (Functional specification for that equipment was prepared as part of WP4). It is worth mentioned, however, that at the time of writing SN2.0 are relatively cheap devices and when combined with additional visibility it could provide for control operation there is an opportunity to optimise the installation of the devices for both ANM and control use hence derive additional financial benefit.

Ref	Area	Description
15	WP5	Financial benefit derived from STPFR capability is mainly associated with avoided curtailment for ANM curtailable connections subject to a cap. This study provides an indication of financial benefits associated with reduction in flexibility procurement where indicative figure for MWh is available (£300/MWh): - Annual reduction in flexibility procurement of 341MWh or ~£102,300 for a highly loaded circuit (ALVE 305) with limited headroom, six sets of SN2.0 installed. - Modelled annual reduction is flexibility procurement of £96,483 with one set installed (for future pipeline ANM sites)
16	WP5	There is no additional impact on OHL conductor design life associated with implementation of STPFR. Static post-fault ratings use a 9% exceedance value, which signifies higher thermal stresses could be sustained by the conductor in the event of a prolonged fault. The deterministic nature of STPFRs and the 10-minute interval for ANM response does not increase any currently accepted risk of exceedance. However, preserved level of risk exceedance relies on the ANM system’s ability to react within the 10-minute STPFR window.
17	WP5	Draft ST Relating to the Installation and Maintenance of OHL Monitoring Devices have been updated with specific detail for 132kV site selection and installation instructions and should supersede previous ST version.

10 The Outcomes of the Project

Running Cool was delivered in five work packages as detailed in Section 5 of this report. The following sections outline the outcomes from each of the work packages.

10.1 WP1 – Recommendations for Change in ANM Control System Architecture

Figure 10 presents excerpts from the WP1 project report.

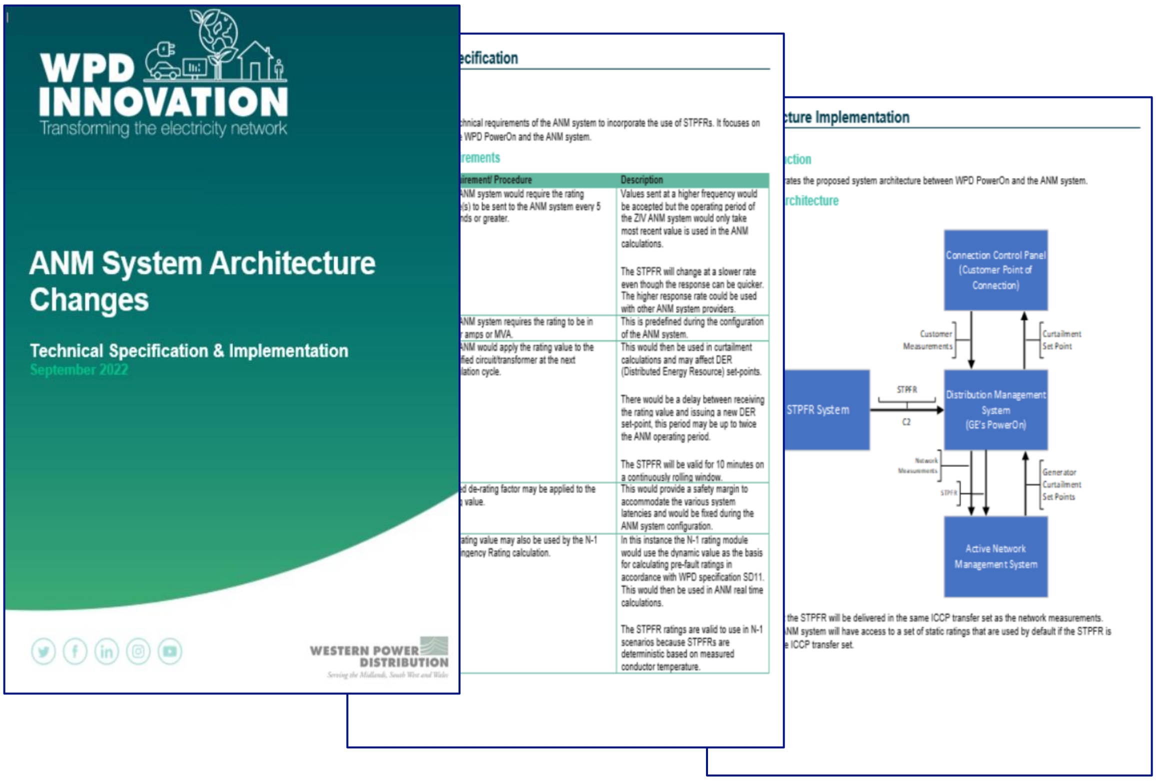


Figure 10-1 WP1 report excerpts

As discussed in Section 5, this report contains details for ANM changes required to enable STPFR capability. Specifically, it outlines:

- Requirements for ANM system architecture changes
- Different implementation strategies for transfer of STPFR values from the source STPFR system to ANM, with a preferred method of implementation being STPFR system sending values directly to the NGED Control System (PowerOn).

10.2 STPFR and Risk Assessment

Figure 10-2 presents excerpts from the WP2 project report.

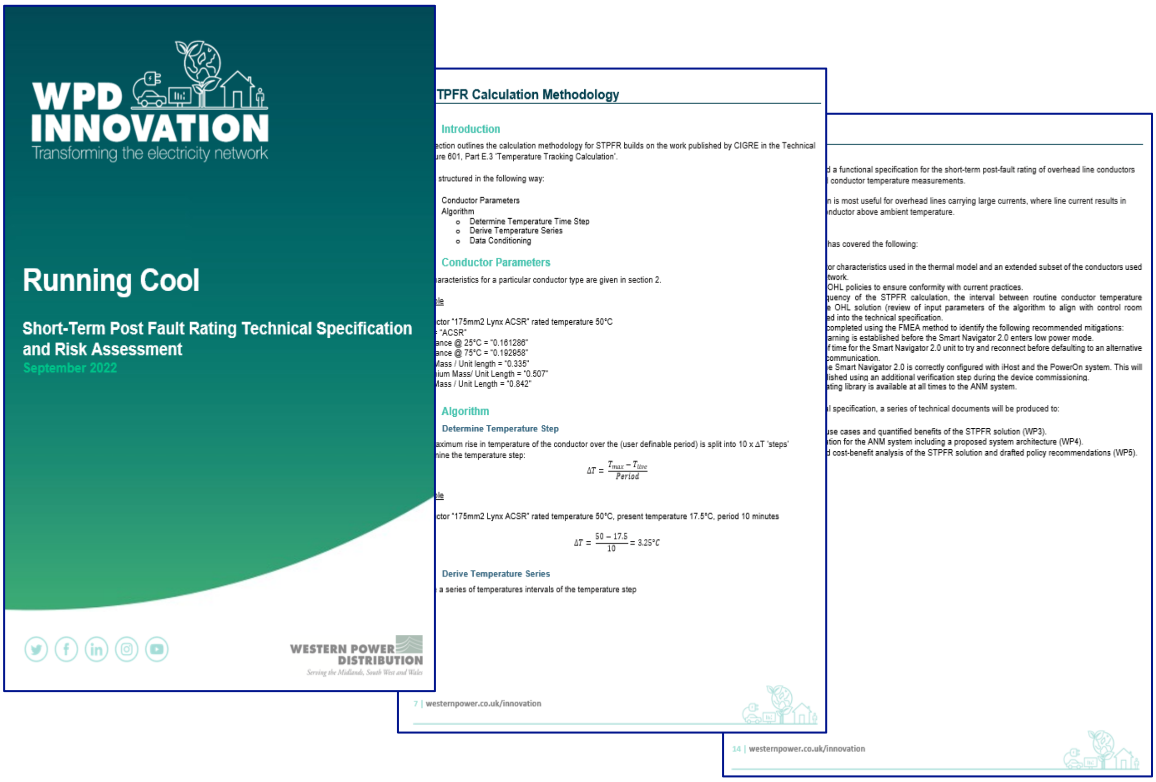


Figure 10-2 WP2 report excerpts

As discussed in Section 5, this document presents a functional specification for STPFR of OHL that exploits the thermal capacity of the conductor material. The calculations is independent on the measurements of other heat transfer mechanism. The conductor temperature is the only parameter required to be monitored in real-time to provide a rating to cover STPFR generation curtailment events.

Risk Assessment is also included within WP2 report. It specifies each process and component of the STPFR solution, identify how it may fail and propose mitigation solutions to manage the failure modes.

10.3 Network Use Cases

Figure 10-3 presents excerpts from WP3 project report. As specified in Section 5, the report contains information about:

- Where equipment was installed
- Methodology for capacity and rating uplift
- Methodology for curtailment analysis for new connections
- Results of the uplift analysis for each site
- Results of the curtailment analysis (observed and modelled)

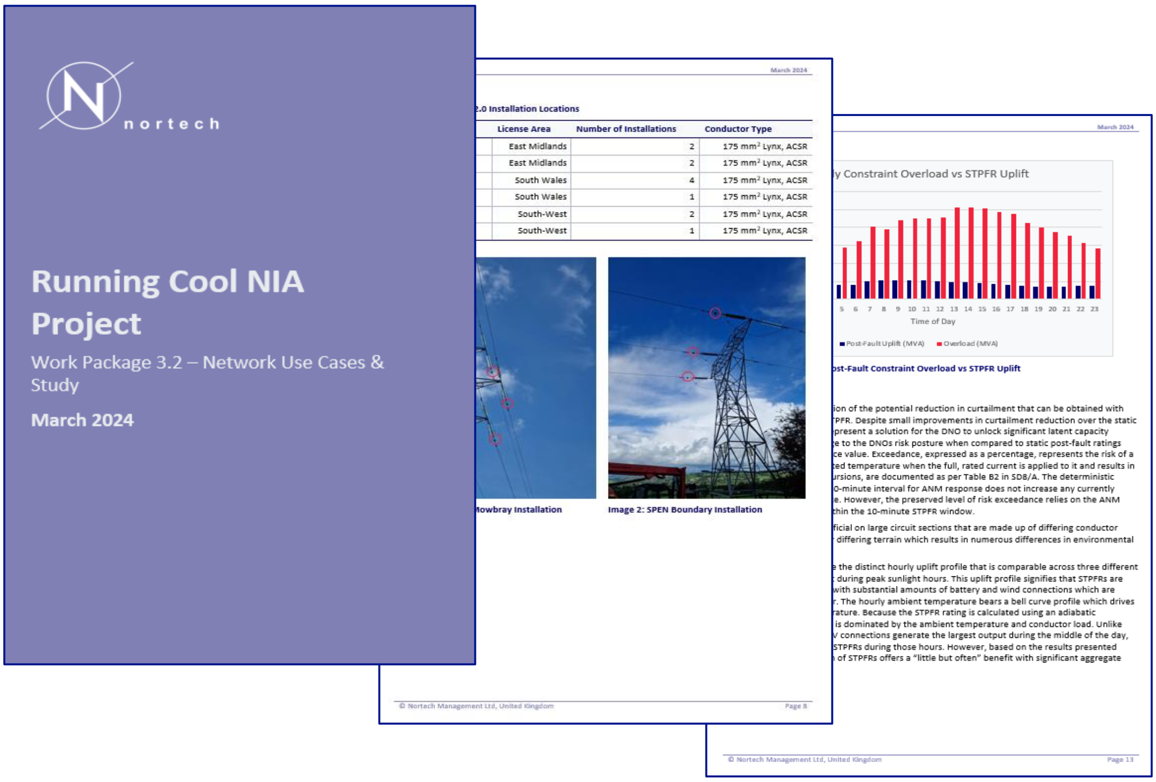


Figure 10-3 WP2 report excerpts

An example of the rating comparison is included in Figure 10-4 below for illustration.

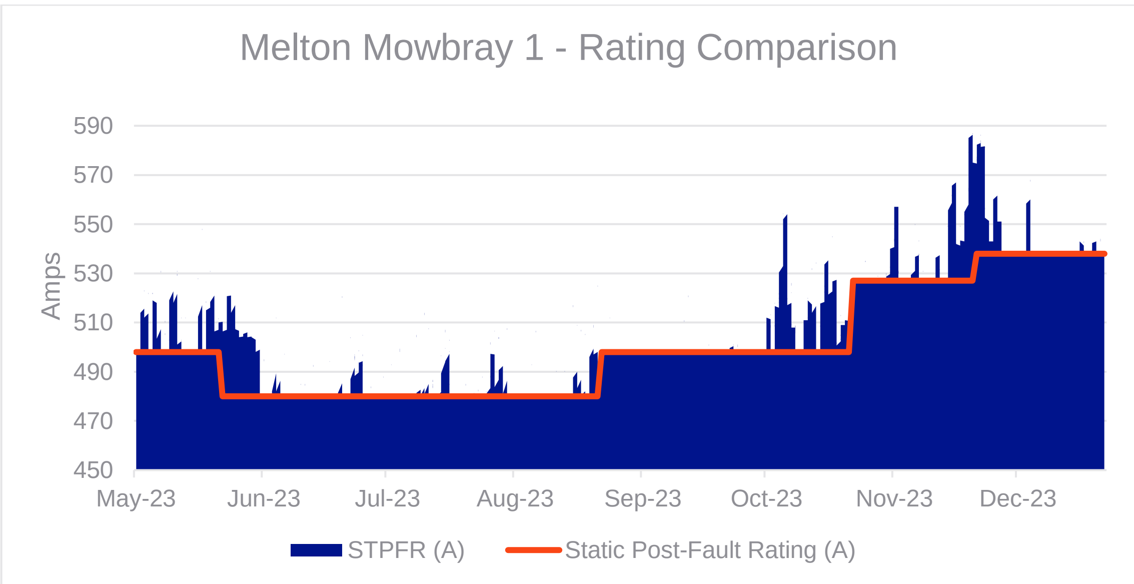
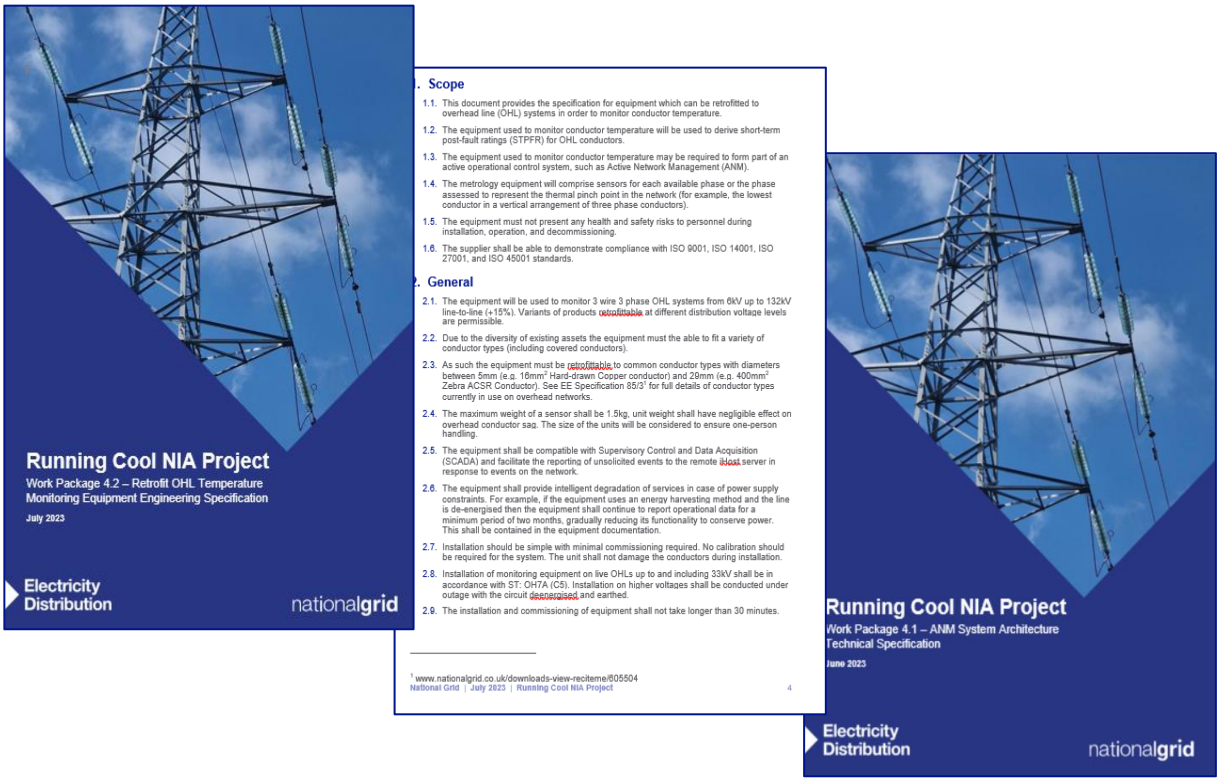


Figure 10-4 Post fault crating comparison for Melton Mowbray site.

10.4 Final Control System Architecture and Device Specification

Figure 10-5 presents excerpts from the WP4 documentation. That include:

- ANM System Architecture Technical Specification that builds on the document prepared as part of WP1
- Retrofit OHL Temperature Monitoring Equipment Engineering Specification



1. Scope

1.1. This document provides the specification for equipment which can be retrofitted to overhead line (OHL) systems in order to monitor conductor temperature.

1.2. The equipment used to monitor conductor temperature will be used to derive short-term post-fault ratings (STPFR) for OHL conductors.

1.3. The equipment used to monitor conductor temperature may be required to form part of an active operational control system, such as Active Network Management (ANM).

1.4. The metrology equipment will comprise sensors for each available phase or the phase assessed to represent the thermal pinch point in the network (for example, the lowest conductor in a vertical arrangement of three phase conductors).

1.5. The equipment must not present any health and safety risks to personnel during installation, operation, and decommissioning.

1.6. The supplier shall be able to demonstrate compliance with ISO 9001, ISO 14001, ISO 27001, and ISO 45001 standards.

2. General

2.1. The equipment will be used to monitor 3 wire 3 phase OHL systems from 6kV up to 132kV line-to-line (+15%). Variants of products retrofittable at different distribution voltage levels are permissible.

2.2. Due to the diversity of existing assets the equipment must the able to fit a variety of conductor types (including covered conductors).

2.3. As such the equipment must be retrofittable to common conductor types with diameters between 5mm (e.g. 16mm^2 Hard-drawn Copper conductor) and 29mm (e.g. 400mm^2 Zebra ACSR Conductor). See EE Specification 85/3[1] for full details of conductor types currently in use on overhead networks.

2.4. The maximum weight of a sensor shall be 1.5kg, unit weight shall have negligible effect on overhead conductor sag. The size of the units will be considered to ensure one-person handling.

2.5. The equipment shall be compatible with Supervisory Control and Data Acquisition (SCADA) and facilitate the reporting of unsolicited events to the remote iHost server in response to events on the network.

2.6. The equipment shall provide intelligent degradation of services in case of power supply constraints. For example, if the equipment uses an energy harvesting method and the line is de-energised then the equipment shall continue to report operational data for a minimum period of two months, gradually reducing its functionality to conserve power. This shall be contained in the equipment documentation.

2.7. Installation should be simple with minimal commissioning required. No calibration should be required for the system. The unit shall not damage the conductors during installation.

2.8. Installation of monitoring equipment on live OHLs up to and including 33kV shall be in accordance with ST: OH7A (C5). Installation on higher voltages shall be conducted under outage with the circuit deenergised and earthed.

2.9. The installation and commissioning of equipment shall not take longer than 30 minutes.

[1] www.nationalgrid.co.uk/downloads-view-reciteme/605504

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Figure 10-5 WP4 deliverables

10.5 CBA and Policy Amendments

Figure 10-6 presents excerpts from the WP5 project reports. Specifically, that includes:

- A Qualitative CBA and qualitative discussion of the impact of STPFR on OHL conductor design life
- Recommendations for amendments in the relevant NGED policies relating to OHL ratings and installation and maintenance of the monitoring equipment.

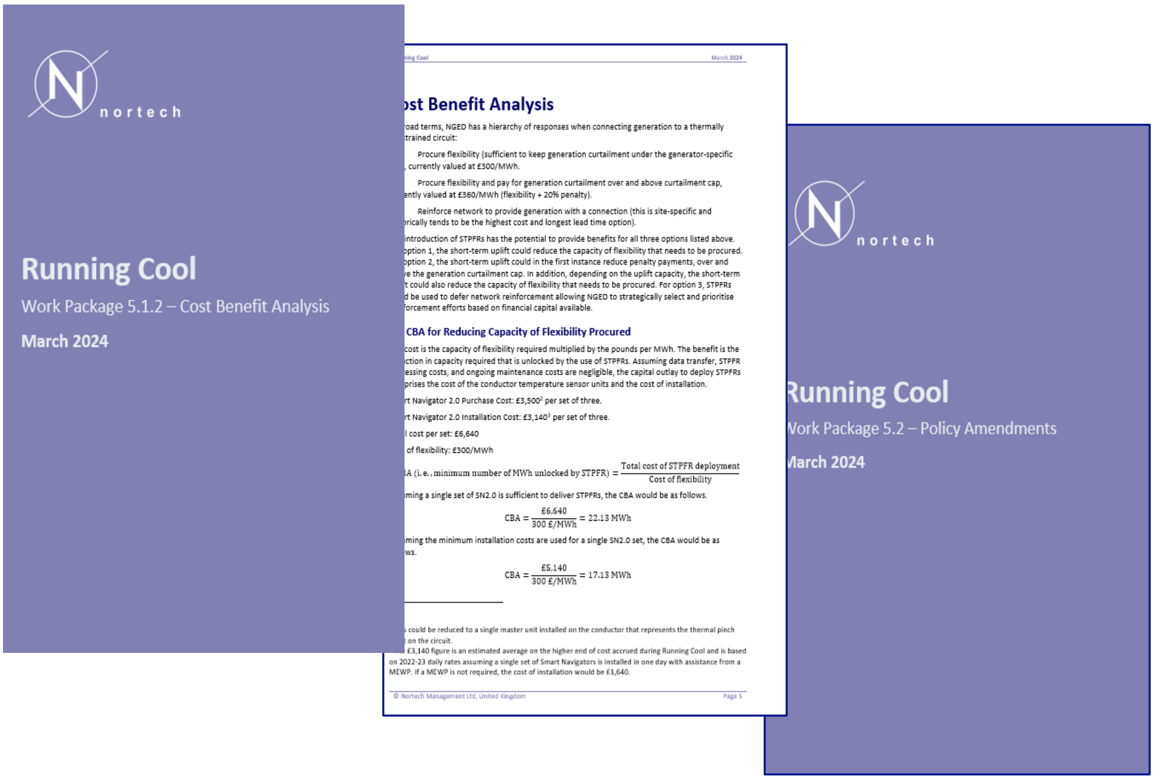

Figure 10-5 WP5 deliverables

Full detail on any of the above reports is available upon request but subject to data sharing requirements.

11 Data Access Details

Information for Running Cool has been published on our innovation website:

National Grid - Running Cool

Specific reports and functional specifications can be requested by submitting a form on the website.

12 Foreground IPR

The following IPR has been generated as part of this project. Ownership is 100% NGED.

- ANM System Technical Specification document
- Retrofit OHL Temperature Monitoring Equipment Engineering Specification

13 Planned Implementation

Running Cool demonstrated clear benefit of the STPFR method when integrated within ANM system. The results presented throughout this report have been generated in a non-live operational environmental and therefore, there is further need to upgrade both ANM system and NGED control system to ensure they are capable of receiving, sharing and actioning upon dynamic STPFR generated in the iHost system.

The following steps have been considered for full method implementation:

- Explore business case to invest in ANM systems to deliver STPFR capability
- Liaise with ANM providers and implement necessary changes within existing ANM architecture (following point 1)
- Test secure delivery of STPFR from iHost to PowerOn and confirm consistency of power system parameters shared between all systems involved
- Integrate STPFR values in the ICCP transfer package along with other network parameters to be shared with ANM providers
- Identify a test location within operational ANM connections to conduct live testing
- Following lessons learnt gathered following the trial, implement STPFR capability across all licence areas

Wider business activities will involve:

- Working with a procurement team to identify most cost efficient OHL temperature sensors that are capable of supporting STPFR method
- In collaboration with DSO team to identify constraining circuits resulting in curtailment/flexibility procurement and make recommendations for STPFR method deployment
- In collaboration with Engineering Policy team develop guidance around placement of temperature sensors
- Implement suggested recommendation into NGED policy documents.

14 Contact

Further details on this project can be made available from the following points of contact:

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15 Glossary

Abbreviation	Term
Access SCR	Access Significant Code Review
ANM	Active Network Management
DER	Distributed Energy Resource
DNO	Distribution Network Operator
DNP3	Distributed Network Protocol
FMEA	Failure Modes and Effects Analysis
LIFO	Last-In First-Out
ICCP	Inter-Control Communications Protocol
NGED	National Grid Electricity Distribution
NIA	Network Innovation Allowance
OHL	Overhead Line
SN2.0	Smart Navigator 2.0
STPFR	Short-Term Post-Fault Rating

16 References

[1] National Grid, “Overhead Line Power Pointer,” January 2022. [Online]. Available: https://www.nationalgrid.co.uk/innovation/projects/ohl-power-pointer. [Accessed 24 01 2023].

[2] CIGRE Working Group B2.43, “Technical Brochure 601: Guide for Thermal Rating Calculations of Overhead Lines,” in *CIGRE Paris*, Paris, 2014.