SIF Alpha Round 2 Project Registration

Date of Submission

Nov 2023

Project Reference Number

10078787 (1)

Initial Project Details

Project Title

Scenarios for Extreme Events - Alpha

Project Contact

John Zammit-haber

Challenge Area

Improving energy system resilience and robustness

Strategy Theme

Net zero and the energy system transition

Lead Sector

Electricity Transmission

Project Start Date

01/10/2023

Project Duration (Months)

6

Lead Funding Licensee

National Grid Electricity System Operator

Funding Licensee(s)

WPD - Western Power Distribution (West Midlands) Plc

Funding Mechanism

SIF Alpha - Round 2

Collaborating Networks

Cadent

Scottish and Southern Electricity Networks Transmission

National Gas Transmission PLC

Technology Areas

Modelling

Resilience

System Security

Project Summary

High impact low probability "extreme events" can have serious impacts on the GB energy system. The GB energy system is rapidly transitioning, with an increased dependency on renewable generation and an increased reliance on electrification: a combination which will lead to greater system vulnerability. The increasing frequency of extreme weather events along with influences of other geopolitical events (COVID / war) can have both direct and indirect impacts on the system. This project sets out to better understand how whole-energy system resilience can be impacted by extreme events, identifying vulnerabilities, and informing future investment planning decisions.

Preceding Projects

Scenarios for Extreme Events

Project Budget

£508,982.00

SIF Funding

£457,899.00

Project Approaches and Desired Outcomes

Problem statement

Provide a summary of the problem that you want to solve through your project.

High-impact low-probability (HILP) events such as extreme weather, pandemics and geopolitical events can lead to scenarios that have serious impacts on the GB energy system. In parallel, the move towards decarbonisation and decentralisation drives system diversification, with increased electrification, leading to a greater reliance on electricity.

Currently, measures for these scenarios are reactionary rather than anticipatory and recent global events have highlighted the limitations of this approach. Whole energy system impacts and interactions between energy vectors and other sectors (i.e. water, telecoms, transport etc.) during these HILP events are not systematically captured. This limits current and future operational resilience.

A methodology with novel use of Model Based Systems Engineering was developed in Discovery Phase to quantify the impact of HILP events and inform a response to them in line with the evolution of energy system operation. Our approach incorporates emerging thinking in areas such as risk management and the financial sector resilience, particularly for costing of extreme events.

This project addresses the Innovation Challenge of 'Improving Energy System Resilience and Robustness' by improving the approach to the identification and analysis of extreme events and their impacts on the GB energy system.

A literature review into existing resilience approaches and engagement with stakeholders demonstrated the following:

- A lack of consistency surrounding terminology -- the future framework hopes to standardise definitions in relation to extreme events
- Learning that could be taken from existing frameworks and examples of best practice e.g. Japan.
- The energy sector has a good understanding of resilience; existing measures are reactive rather than anticipative.

The proposed framework will enhance existing knowledge and standardise approaches across the GB energy system.

The Alpha project output is anticipated to be a prototype model that predicts the impacts of future HILP events. This capability would be developed and integrated into business-as-usual activities, including resilience planning and Future Energy Scenario (FES) work.

Users of the innovation would be all networks, operational and planning teams who would use the project outputs to better understand and pre-empt the impact of extreme events on the grid and wider energy system.

Innovation justification

A novel, innovative solution

The cross-sector impacts of extreme events, such as pandemics and severe storms, necessitates a modelling approach with a broader scope than that of current industry tools, which mainly cover subsets of energy system assets. Our proposed solution will allow the FSO to be proactive in assessing the impact of low-probability events and identify interventions to improve energy system resilience, with the potential for significant cost savings by reducing the impact of system failures. This project addresses the Innovation Challenge of 'Improving Energy System Resilience and Robustness' by enhancing the approach to the identification and analysis of extreme events and their impacts on the GB energy system.

Built on a powerful modelling approach

We considered a range of modelling approaches during the Discovery phase (e.g. Bayesian modelling, system dynamics modelling). We propose that Model-Based Systems Engineering (MBSE) is the best framework to construct a prototype system resilience model due to its flexibility and ability to contain and display complex information in an intuitive way. Our stakeholder engagement has highlighted the case of the Common Infrastructure Model, which is also built using an MBSE approach and could be leveraged to provide datasets for Alpha phase. We will develop the proposed model from its current TRL 2 (technology concept formulated) to TRL 7 (system prototype development in relevant environment), building a platform for further development

in the Beta phase toward business-as-usual operation.

Informed by experience

We have the advantage of experience across a range of current and previous SIF projects, which we have used to inform our approach to this programme. In particular, conducting early and proactive cross-sector engagement with stakeholders representing electricity, gas and finance industries has allowed us to maximise the value of project partners during the Discovery phase. Our Alpha project will seek to build on this, engaging with the water industry to understand how loss of the energy system impacts other essential utilities. Our project delivery will recognise the complementary synergies with other SIF projects (WARN & CReDo+) and continue work collaboratively to align the inputs and outputs of each model.

In collaboration with stakeholders

We built a coalition of industry partners with expertise across the GB energy sector and have leveraged this to propose an innovative modelling approach to understand resilience at a whole-system level. We have conducted group workshops and individual interviews to gather stakeholder views and enable challenge of our work, which has allowed early addressing of issues and improvement to the Discovery phase outputs.

Ideal for the SIF programme

This project involves developing a novel approach that cannot be resourced via existing business practices. It can deliver significant benefits to the way energy system reliability is managed but must be developed and tested separately to business-as-usual tools and processes to ensure it does not impact on current security of supply. It brings together project partners across the electricity, gas, and water sectors, as well as academia. This unconventional coalition has offered a uniquely diverse range of thought during the Discovery phase and will continue to do so in the Alpha phase. This project takes cross-industry holistic approach that cannot be undertaken by a single network/ organisation. The strategic innovation fund is therefore the ideal vehicle to both develop and deliver this approach and share outcomes and learning between networks.

Impact and benefits (not scored)

Financial - future reductions in the cost of operating the network

Environmental - carbon reduction – direct CO2 savings per annum

Environmental - carbon reduction – indirect CO2 savings per annum

Revenues - improved access to revenues for users of network services

Revenues - creation of new revenue streams

New to market - services

Others that are not SIF specific

Impacts and benefits description

The pre-innovation baseline is the networks' current approach to planning for resilience. This is based upon models and assumptions established ~50 years ago, relevant to a less interconnected world with more centralised, large GB generation and lower societal dependency on electricity. The current approach is reactive and siloed, and leaves networks unable to assess the full extent of the disruption that could result from HILP events, and therefore unable to prioritise projects and response plans that would deliver maximum benefit in terms of minimising impacts to the GB energy consumer.

The proposed modelling solution will give the energy companies, Government, and the regulator the information that they need to effectively plan and enact changes that will optimise energy system resilience with lowest cost to the GB consumer. The benefits of this are intuitively obvious yet difficult to quantify: There are two possible sets of unknown resilience-building interventions, one resulting from the innovation, the other from the baseline, provide a set of unknown benefits should some event, with unknown low probability, occur.

Insights into the benefits of the modelling could be gained from NGESO's current performance metrics and Regularly Reported

Evidence (RRE). Once a functional model exists (Beta Phase), it may be possible to perform a post-event analysis to identify whether the outcomes could have been predicted in advance.

For now, our approach to quantifying benefits has been to develop a prototype benefit model. This assesses the increase in benefits realised through optimising the selection of options based on information, rather than selecting randomly. This suggests (indicative only) that, on average, good information can increase the benefit of resilience interventions by a factor of 3. Work to improve the quantitative basis and sophistication of this model will continue in Alpha to allow a more robust evaluation of benefits to be developed.

Qualitatively, the benefits from the model are:

- **Financial -- optimising future cost of operating the network**

This project will aid investment and planning decisions by providing greater certainty over likely future costs from extreme events and assessing the most cost-effective mitigation strategies and 'future-proofing' actions. It will help limit the severity of detrimental impact to the energy system, and reduce long-term costs from remedying unexpected issues. These improvements should feed through to the procurement process, with better planning will enabling more competitive tendering for products and services.

- **Environmental -- direct and indirect CO2 savings per annum**

Modelling may allow improved forecasting of potential power shortages, reducing reliance on fossil-fuelled backup plants; hence reducing carbon emissions.

- **Revenues -- creation of new revenue streams**

It is possible that the approach taken can be exported to system operators in other countries, whose energy systems face the same challenges as GB's.

- **New to market -- services**

The ESO has been at the forefront of pioneering smart approaches to system flexibility over recent years. This project can identify areas where similar smart approaches are possible for system resilience. This will provide benefits by further opening up the energy market to new participants, products and services to replace existing high-cost items with more innovative solutions.

- **System benefits - Improved system resilience**

Improved understand of system vulnerabilities to extreme events will inform the investment and planning for improved system resilience, reducing potential future costs incurred should a disruptive event occur. The benefits of these savings could be any combination of financial, environmental, or social.

- **Operator benefits -- Regulatory Compliance**

Anticipated license conditions of the FSO will require the ability to both assess system resilience and provide recommendations to improve system resilience. This project seeks to address both requirements.

Teams and resources

Who will be involved with the delivery of the Project during the Alpha phase?

For our Alpha phase project, we propose a continuation of the same project partners, with following exceptions:

- Withdrawal of Lloyd's of London as a prototype model will seek to represent a limited number of events and impacts.
- Both SSEN Distribution and NGED have withdrawn themselves as partners, citing resource constraints and the commercial burden of supporting a SIF project in a limited capacity. They have, however, offered letters of support for the project and are happy to provide SME support into workshops and respond to information requests outside of the SIF contract.
- Addition of United Utilities as a consulted organisation via a letter of support. United Utilities will represent the views of a water utility both in terms of reliance on the energy system and impacts on customers.

Our delivery will be though the core delivery team and network operator partners.

Core delivery team:

- **National Grid ESO (lead partner):** As the electricity system operator for Great Britain, ESO plays a central role in the

management of energy supply within GB. With the anticipated creation of a Future System Operator (FSO), and the new role of Office of Resilience and Emergency Management, they will be directly involved in the development as ultimate owners and users of the project outputs.

- **Frazer-Nash Consultancy**: With industry leading expertise in systems engineering and extensive experience in modelling complex systems, Frazer-Nash will take a lead role in the development of a prototype model within Alpha. Frazer-Nash will also undertake the cost-benefit analysis and provide project management support into ESO.
- **Met Office**: With expertise in climate data and modelling to enable better predictions and decision making in severe weather events, the Extreme Weather team bring significant experience in supporting the energy sector. They are the source of weather and climate data so can advise and support how this data can be used in future phases of the project.
- **University of Strathclyde:** With expertise in electrical systems innovation, future power systems and resilience, the University of Strathclyde has extensive expertise in power system operation and analysis including modelling, economics, dynamic behaviour, protection, and control. All these aspects are crucial for understanding complex mechanisms related to power system resilience.

Network operator partners:

- **SSEN Transmission**: Responsible for the electricity transmission network in the north of Scotland, SSEN-T provide insight into the challenges facing TO assets across some of the most challenging terrain in the UK.
- **National Gas Transmission:** Owning, managing an operating the national gas transmission network in Great Britain, NGT will provide insight into the networks capability and future requirements whilst ensuring the end solution can be deployed as business-as-usual at the end of the project.
- **Cadent Gas:** Owning, managing, and operating the largest natural gas distribution network in the United Kingdom, Cadent provide insight into the structure of the gas distribution network, existing resilience plans and support the identification of system vulnerabilities.

No physical resources or equipment will be required for our proposed Alpha phase delivery. Models will be developed within software under existing licences at no material cost to the project.

Through our Discovery phase, we have introduced the project to the DESNZ Downstream Gas and Electricity Resilience (DGER) team and the Energy Emergencies Executive Committee (E3C). The project team have arranged to present the findings of the Discovery phase at their next E3C meeting (5th August). We would anticipate further continued engagement with DGER, E3C and relevant Task Groups throughout the course of Alpha as key project stakeholders.

Project Plans and Milestones

Project management and delivery

The project will be managed by ESO, with Frazer-Nash providing support in a project management and coordination role. In WP6, weekly update meetings will be held with the project partners and monthly progress meetings with network subcontractors. This approach will make best use of the time available form the wider network partners, whilst ensuring day-to-day tasks and technical challenges are resolved by project partners in a timely manner.

Building on Discovery phase learnings, we will seek to facilitate in-person meetings, where possible, fostering close working relationships and collaborative outputs.

The PMT and project delivery schedule for the Alpha phase are attached as Appendices to the submission. They show the tasks and resources needed to address the technical challenges identified during the Discovery Phase. In summary, we propose six Work Packages (WPs) for delivery during the Alpha Phase:

- WP1 -- Basis of design
- WP2 -- Information Collation and Scenario Building
- WP3 -- Development of inter-network dependencies and resilience measures
- WP4 -- Prototype model development
- WP5 -- Project value and benefits analysis
- WP6 -- Project management and communications

WP1 forms the basis from which WP2 and 3, 4 and 5 are developed. WP2 and WP3 inform the development of the prototype model in WP4. WP5 takes agreed scope from WP1 and the understanding developed in WP2, 3 and 4 to develop the benefits analysis. WP6 monitors and reports progress of the other work packages throughout the Alpha phase.

We propose to use a shared development and collaboration environment such as SharePoint / OneDrive / Teams to facilitate faster information sharing and effective collaboration.

The project will adopt a rigorous Risk Management Process to identify, manage, mitigate, monitor, and communicate project risks throughout delivery.

Risk Identification -- Proactive identification of risks via engagement with all stakeholders, via dedicated risk workshops and ad-hoc identification during day-to-day project business.
Risk Monitoring and Mitigation -- Identified risks will be logged on the risk register with a risk owner and mitigation plans agreed.
Risk Communication -- Proactive, early communication of risks to relevant stakeholders is key to effective risk management. The risk register will be updated and shared with the project partners on a regular basis to foster a common understanding.
Risks are defined in the PMT and will be reviewed and updated monthly throughout Alpha phase.

A key risk recognised within this project is in the scoping and development of a modelling approach that provides a simplified representation of the energy system but does not become simplistic where its value may be compromised. The objective of WP1 is to address this, incorporating a broad range of stakeholder views on what the model should be, and how it should be used.

No stage-gate approach is required due to the short duration of Alpha Phase and breakdown of work packages and deliverables for each.

This work has no potential for supply interruptions for customers or impact consumers access to energy services they require. A fundamental aim of this project is to better understand system resilience to protect consumers in the future

Key outputs and dissemination

By the end of the Alpha Phase, we will have developed a prototype model, demonstrating how specified scenarios of extreme events will impact a section of the GB energy network.

To do this we will firstly agree the basis of design in Work Package 1 (WP1), defining what a model needs to do and how it will be used. This basis will inform the scope for information gathering and building specific scenarios for weather and non-weather

events in WP2.

This scope also will bound the development of inter-network dependencies for electricity, gas, and water for WP3. Understanding these dependencies will help us develop agreed resilience measures (or metrics) for the GB energy system. These measures will then be assigned impact ratings (e.g. low, medium, high) for the system - maturing the risk assessment framework developed in the Discovery Phase. WP3 will also develop a high-level representation of the system, which will highlight key interdependencies between energy and utilities.

Work Package 4 will build upon the system representation developed in WP3 to develop a small-scale prototype model. The purpose of this model is to take input scenarios developed in WP2 and model impacts to an identified section/ region of the GB energy system. This prototype model will be limited in geographic scope to ensure it is realistic to build and validate within the Alpha phase. The value of this model will be further refined and reported as part of our cost benefit analysis (WP5).

The overarching WP6 will be devoted to monitoring and communicating progress to stakeholders through weekly project meetings with partners, and monthly progress reporting. Lessons learnt will be summarised within monthly reports and implemented in subsequent months.

Below is a summary of outputs and owners for each work package.

WP1 - Basis of Design -- Fraser-Nash Consultancy (Owner: FNC):

- Basis of design report
- Vision for end of Beta model (All partners)
- Goals for Alpha model (All partners)

WP2 - Information collation and scenario building:

- Register of archetypal scenarios which encompass known extreme events -- Owners: Met Office for weather, FNC for non-weather
- Agreed level of modular representation for the energy system, describing enablers, dependencies and existing resilience -- Owner: FNC

WP3 - Development of inter-network dependencies and resilience measures

- MBSE representation of the GB energy system showing relationships and dependencies both cross-sector and with supporting utilities -- Owner: FNC
- Agreed resilience measures and metrics at GB energy system level with associated system failure impact scores -- Owner: ESO

WP4 - Prototype model development -- Owner: FNC

- Prototype model development report
- Output analysis from the Alpha phase test case

WP5 - Project value and benefits analysis -- Owner: FNC

- Cost Benefit Analysis report

WP6 - Project management and communications -- Owner: FNC

- Project Management Reports

The model outputs, and the model itself, may contain sensitive information potentially identifying vulnerabilities within the GB energy system and could therefore be exploited for malicious purposes.

Dissemination of the broader Alpha phase outcomes, learnings, and findings will be achieved through existing established SIF communication routes, e.g. show & tells and ENA Smarter Networks Portal. Specific learnings that are deemed to be sensitive will have restricted distribution within the project partnership and identified key stakeholders. The key project outputs and lessons learned will also be communicated within established forums such as the E3C and the relevant Task Groups.

Commercials

Intellectual property rights, procurement and contracting (not scored)

All project partners will use the default IPR arrangement. Compliance with the IPR arrangements as defined in Chapter 9 of the SIF Governance document will be ensured for each of the project partners via the contract that they will each sign with ESO to participate in the project.

It is understood by the project partners that knowledge transfer is one of the key aims of the SIF. Benefits of the project will be maximised by the ability of other licensees and interested parties to be able to use learning from the project to improve outcomes or reduce costs for the GB consumers.

Foreground IPR which is produced by the project, such as a description of model and the benefits that can accrue, will be outlined in the Alpha Phase reporting in sufficient detail to enable others to identify whether they wish to use that IPR. Confidential details of IPR, such as model development, will not be disclosed. However, sufficient information will be provided to enable other licensees to understand the model being developed and its applicability to their own networks. The University of Strathclyde will retain rights to discuss their contribution at academic seminars/events.

Commercialisation, route to market and business as usual

The objective of the "Scenarios for Extreme Events" project is to develop a modelling toolset that can be used by the ESO (FSO) to satisfy the following expected license conditions:

- Provide a measure of resilience within the GB Energy System and understand how resilience may change because of network development (Future Energy Scenarios)
- Provide recommendations to networks that may improve the resilience of the GB Energy System.

A central element for both expected license conditions will be the ability to understand how the GB Energy System may be impacted by scenarios of unplanned extreme events. This project has been structured to directly address this need, developing a modelling framework that provides a simplified representation of the GB Energy System which can be interrogated with scenarios of extreme events. The objective is to better understand the whole-system resilience of the GB Energy System and its vulnerabilities to extreme events, identifying how specific systems within the energy system could be compromised and how these may lead to cascading effects across the GB Energy System and to the wider critical national infrastructure.

The developed modelling toolset will ultimately be owned and operated by the ESO (FSO) who will engage with government and network operators to consider the GB system resilience to extreme events, and better understand potential impacts and cascade failure effects. Outputs from any modelling will need to be treated as sensitive information, therefore access to both the developed model and output information will be controlled.

Within the delivery of Alpha project, the project will begin to outline and defined the core elements of a business-as-usual deployment:

- Identification of the key personnel involved in the operation of a model, identifying key roles and responsibilities both for the core operational team and wider stakeholder groups.
- Outlining the processes that define how a model will be used, considering how scenarios are defined, data sources for input conditions and the subsequent actions taken based on model outputs.
- Development of a prototype tool providing an illustrative representation of outputs that can be evaluated and shared with identified stakeholder groups.

Work Package 1 "basis of design" seeks to define the core requirements, philosophy and outputs from a future developed model. Work package 4 will use this basis of design to development a prototype modelling framework.

Within the assembled team, the project partners have the core capabilities of industry insight and modelling expertise to develop a prototype model. The scaling of this into a business-as-usual deployment would require this capability to be embedded within a specific FSO team. This alpha phase project will begin to define what such a team may look like and their associated responsibilities.

Within ESO, this project has been sponsored by Audrey Ramsey, System Restoration Senior Manager and John Zammit-Haber,

Energy Security Senior Manager.

Policy, standards and regulations (not scored)

Government regulation of the energy sector is changing due to the UK Energy Security Bill. ESO is transitioning to the Future System Operator (FSO). This project directly supports the FSO which will hold responsibilities across both the electricity and gas systems, including a key role assuring emergency preparedness and providing a whole system view of energy resilience.

The Alpha phase will build on the Risk Assessment Framework developed in Discovery phase to better inform resilience planning. This will support decision making in a way that is consistent with existing government practices. We do not currently envisage any standards needing to change for the project outputs to progress into business as usual. However, an overview of these standards, and this project's potential influence on them, is listed at the bottom of this answer.

Collaboration with ESO, partners and identified stakeholders in Alpha will help clarify any impacted regulations, policies, and standards. Work Package 1, will defined the basis of design, of which policy, standards and regulatory requirements will be a core consideration.

In Discovery phase it has become clear that a model which identifies events likely to impact the GB energy system could be used nefariously, therefore the required level of security classification of the model and the outputs will be defined in Alpha phase. Until security measures are agreed, the model development will use dummy or anonymised data to remove the need for any security classification of the model or its outputs.

We do not currently anticipate that any future project phase will require a derogation or exemption.

A summary of relevant gas and electricity standards is below:

Relevant electricity standards reviewed include:

- Security and Quality of Supply Standard (SQSS), the Grid Code, Connection and Use of System Code (CUSC), European Network Codes (ENC), System Operator Transmission Operator (STC) Code and the Digitalised Whole System Technical Code (WSTC).
- The SQSS establishes the expectations and obligations for the Electricity System Operator (ESO), Transmission Owners (TOs) and Offshore Transmission Owners (OFTOs) regarding the security and reliability of the National Electricity Transmission System (NETS).
- The Grid Code outlines aspects of NETS operation, and technical requirements; including voltage control, frequency management, grid connection requirements, operational planning, and communication protocols.
- The CUSC is the contractual framework for connecting to and using the NETS.
- The ENC cover grid connections, markets, and system operation, to provide a sustainable, secure, and competitive electricity market across Europe.
- The STC defines the relationship between the TOs, OFTOs and the ESO.
- The WSTC project proposes to simplify, align, and digitalise GB electricity technical codes.
- Model outputs from this project may inform the WSTC and future updates of electricity codes.

Relevant gas standards reviewed include:

- The Uniform Network Code and The Gas Regulations 2019.
- The Uniform Network Code is a set of rules and procedures that govern the transportation of gas between different parties, such as Transporters, Shippers, Users and Independent Gas Transporters (Transmission).
- The following are descriptions of codes in the Gas Regulations:
- The Balancing Code governs the balancing of gas supply and demand on the gas transmission and distribution networks.
- The interoperability Code sets standards and procedures for the interoperability of gas transmission systems.
- The Capacity Allocation Mechanisms Code governs the allocation of gas transmission and storage capacities to market participants
- The Tariffs Code establishes the framework for setting gas transmission and distribution tariffs.

Value for money

For our Alpha Phase project we are requesting £457,899 of SIF funding. The total cost of delivering the work scoped for the Alpha Phase is estimated to be in excess of £508,982 once the 10% contribution from all partners is accounted for.

The funding requested will enable our partners who are leading and contributing to each of the Work Packages to fund their support. A detailed breakdown of this funding across the six identified work packages is provided within the project plan. Network partners will provide support and contribute in-line with the funding they have requested. Identified supporting non-partner network operators will support and contribute to the project outside of the funding request.

Our partners' have costed their funding requests based on their standard industry rates reduced by 10%, representing a 10% contribution from private funds. This also provides assurance that the costs compare favourably with normal industry rates.

The £457,899 funding requested will be split across project partners as follows:

Project Partner Funding Requested

National Grid Electricity System Operator - £70,342

Scottish and Southern Electricity Networks Transmission (SHET) - £4,354

Cadent Gas Ltd - £4,050

National Gas Transmission PLC - £4,980

University of Strathclyde - £87,405

Met Office - £67,883

Frazer-Nash Consultancy - £218,885

Frazer-Nash Consultancy and Met Office have joined as project partners for Alpha phase, having previously been sub-contractors in Discovery. No further Subcontracts are required within the Alpha phase.

No additional funding sources are being used to support this project. All work will be conducted within existing facilities and using existing software licenses

Associated Innovation Projects

- ○ Yes (Please remember to upload all required documentation)
- ◉ No

Supporting documents

File Upload

No documents uploaded

Documents uploaded where applicable?

☑