Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Feb 2024

Project Reference Number

NIA2_NGET0055

Project Registration

Project Title

Knowledge Elicitation of Risks to Assets Under LightNing Impulse Conditions (KERAUnIC)

Project Reference Number

NIA2_NGET0055

Project Licensee(s)

National Grid Electricity Transmission

Project Start

March 2024

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Tinashe E Chikohora

Project Budget

£558,656.00

Summary

There is an urgent need to understand, quantify, and assess the lightning risk threat on the fast-expanding electricity network assets. Previous related projects focused on real-time fault management for distribution networks offering limited transmission level insights. Yet, growing evidence has it that climate change is influencing lightning, in terms of formation, severity, patterns, frequency, and distribution. This project aims to develop novel strategies to assess lightning risks for NGET transmission infrastructure assets considering past climatological data and adding superimposed long-term climate site-specific trend projections. Because climate change influences lightning occurrence and patterns, the project can inform the design and location of new energy infrastructure, ensuring appropriate lightning protection. The project will improve system planning, regulatory compliance, lead to reduced damage, downtime and maintenance costs.

Third Party Collaborators

University of Bath

Nominated Contact Email Address(es)

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Problem Being Solved

Lightning strikes are a big threat to the security of energy infrastructure. In the UK, the most severe power outage recently caused by lightning strikes was the 2019 blackout. A lightning struck a 400kV overhead transmission line in Cambridgeshire followed by a nearly simultaneous generation loss of 2.1GW, comprising of loss of generation at Hornsea One offshore windfarm and generation at Little Barford. In October this year, a lightning strike at a recycling plant in Oxford caused a huge gas explosion and local power outages, as reported by BBC.

The energy sector's 2035 net zero ambitions require large-scale investment in energy infrastructure to generate and transport electricity particularly from renewables. As forecasted by Ofgem, £90bn investment in networks is needed between now and 2030.

Such big expansion exposes electricity system assets, overhead lines, poles and substations, to potential lightning strikes. The consequences would be asset failure, reduced lifetime to mention a few, and in the worst cases prolonged outages.
There is growing evidence that climate change is influencing lightning, in terms of formation, severity, patterns, frequency, and distribution. One United State study published in the journal Science suggests that for every degree of rise in global average air temperature, there is a 12% increase in lightning strikes (Romps et al., Science, 2014, doi: 10.1126/science.1259100). Newcastle University's research concludes that global warming brings a very complex pattern of change in lightning density across Europe (Kahraman et al., Environmental Research Letters, 2022, doi:10.1088/1748-9326/ac9b78).
There are many uncertain climatological factors affecting the formation of lightning, and there is no consensus on how lightning will unfold in climate change. Strong global climate drivers, such as the El Nino Southern Oscillation (ENSO) and the Madden Julian Oscillation (MJO) can increase the number of thunder hours by approximately 400 in tropical central Africa, even though both phenomena are caused by equatorial sea surface temperature anomalies. By contrast, the European climate is influenced by the North Atlantic Oscillation (NAO), such that the relative climate impact of atmospheric variability originating at middle and low latitudes remains unquantified.
Such changes in the natural behaviour of lightning have significant implications for our energy infrastructure. The electricity systems should be well prepared for the worst cases rather than hoping for the best. There is an urgent need to understand, quantify, and assess the risks from lightning strikes on the fast-expanding electricity network assets. This will provide essential guidance for the lightning protection of valuable assets during planning/operation stages to enhance system supply security. The knowledge and findings can also inform new standards for lightning protection of the whole electricity system. Storm Resilience (UKPN, 2019-2023) was one recent and pioneering project that studied the impact of lightning strikes on electricity assets. However, like most previous research, it was focused on real-time fault management of distribution networks offering limited insights for transmission networks.

Method(s)

The initial project aims will be achieved by connecting data from multiple interdisciplinary domains and by applying novel machine learning and data analytics approaches. Lightning flashes could be used as a proxy measure for severe weather, which is thought to become more important as part of global warming. Lightning was recently elevated to become an essential climate variable by the World Meteorological Organisation (WMO). This means that lightning data will be collected and archived, including thunder hour data provided by ground-based lightning detection networks and earth-observing satellite missions.

New thunder hour data from Earth Networks with approximately 5.5 km spatial resolution will be used. There shall be use of the data describing extreme events collected in project WELLNESS (NGET/Whole Energy System Resilience Vulnerability Assessment/SIFIESRR/Rd2_Alpha | ENA Innovation Portal (energynetworks.org)), and data from flood sensors installed under ERA (Environmental Risk and Assurance (ERA) | ENA Innovation Portal (energynetworks.org)). The project understands the importance of sharing data and knowledge, thus it will ensure that the data, results, models, and other key outputs are compatible to best practise standards to match other networks projects platforms/standards like in CReDo+ Climate Resilience Demonstrator (extension to new climate risks) | ENA Innovation Portal (energynetworks.org).

Historic lightning data will be used to predict climate trends whilst real-time satellite observations will be used to by using innovative machine learning methods. Particular emphasis will be placed on quantifying and discriminating the main atmospheric processes driving climate change, such as the North Atlantic Oscillation, Madden Julian Oscillation, and the El Nino Southern Oscillation.

The results of these novel analyses of actual lightning observations will finally be compared to the numerical simulation of climate trends of lightning reported in recent studies e.g., Kendon et al., UKCP 2023, Suoto et al., 2023a & 2023b, Kahraman et al., 2022.

National Grid's Transmission Entry Capacity (TEC) register provides a list of projects that hold contracts for existing and future connection projects. Further, National Grids' Infrastructure projects provide information regarding the project to be delivered. Complimentary datasets will be used to build a network that can be the best representative for the future so as to detect hotspots and most vulnerable locations from lightning strikes.

Historical lightning strike events and failure data provided by NGET will be used to build the lightning-infrastructure relationship and a scheme developed to differentiate non-lightning failures. There are some existing models available in the literature that describe how lightning strikes affect various electricity assets. Parameters of existing lightning strike models will be tuned to reflect the specific features of assets of various (operational) types, locations and complement trained models that look at historical events with limited asset data.
Quantum Geographic Information System (QGIS), a free and open-source cross-platform application that supports viewing, editing, printing, and analysis of geospatial data will be used to build/demonstrate the proposed capabilities.

Scope

Work package 1: Forecasting of regionally climatology thunderstorms and lightning hazard.

Develop a regionally specific climatology of short-term and long-term thunderstorm and lightning hazards, including all types of lightning, such as cloud-to-ground and in-cloud lightning. The results will be provided in Excel spreadsheets and QGIS shapefiles.
Milestone 1: short-term lightning hazard forecasting
Milestone 2: long-term lightning hazard mapping

Work package 2: The mapping of UK electricity infrastructure.
Create a map of the UK electricity infrastructure. This map will include existing assets, those to be built, and those potentially to be built. The results will be provided in Excel spreadsheets and QGIS shapefiles.
Milestone 3: existing NGET infrastructure mapping
Milestone 4: future NGET infrastructure mapping

Work package 3: Understanding and modelling the impact of lightning strikes.
This work package we will build models by combining historical events and existing models, to assess how lightning would affect different network assets. Data analyses will be designed for recorded data to identify the relationship between lightning strikes and their impact on assets.
Milestone 5: Data fusion for model building
Milestone 6: Data analytics for impact identification

Work package 4: Assessment of the impact of lightning strikes on infrastructure and system.
This work package will present the assessment of consequences on electricity assets and system-level supply. Metrics will be designed to identify the hot spots of lightning across geospatial scales under different energy pathways and climate scenarios. This will be delivered in the form of an Excel spreadsheet. Recommendations for improving the protection of existing assets and heatmaps for future lightning threats will be delivered in a report.
Milestone 6: Impact assessment on assets
Milestone 7: Impact assessment on system supply

Work package 5: A QGIS-based visualisation platform
A QGIS-based or equivalent platform will be developed to integrate and visualise the data and results from work packages above.
Milestone 7: QGIS platform for analysis and visualisation

Objective(s)

- Assess past and future lightning trends in the UK to estimate the uncertainty of the predictions to develop novel lightning (climate) model corrections and analyses.
- Conduct secondary lightning forecasting.
- Map existing & future UK electricity infrastructure under different pathways of net zero for long-term lightning strike (hotspots) risk assessment.
- Use the emerging real-time lightning data from lightning imager on board the geostationary Meteosat Third Generation (MTG) satellite to produce short-time lightning predictions.
- Use MTG satellite in geostationary orbit for the novel lightning imaging sensor to quantify lightning in real time and thereby enable novel monitoring of weather and climate variability, with unprecedented precision (commissioning phase expected in spring 2024).
- Combine and check any corelation between synchronized local environmental data and failure data.
- Use machine learning and other mathematical techniques (such as wavelet-based decomposition) to analyse the recorded current and voltage fault profiles even where a Delayed Auto Reclose (DAR) action is triggered without supply interruption.
- Conduct a system-level analysis considering the failure of key assets, scenarios of supply, demand, and weather conditions, to identify potential consequences particularly when the system is under stress.
- Design a set of metrics (categorised by infrastructure type, consequences, severity, probabilities) to measure the severity (heat map) of asset/system impact.
- Develop/upgrade a geographical information systems (GIS) platform to integrate developed/novel geospatial data.
- Integrate other platforms such as ArcGIS ensuring flexibility for users to analyse lightning strike impact under various scenario and conduct statistical analysis through Python Console to visualise results interactively.
- Inform hardening existing towers and grids by investigating their protection schemes, measures and standards, and assess whether they are sufficient for protecting these assets against future lightning threats.
- Inform resilient and robust system planning, by providing knowledge and hotspots in future lightning in the GB under different scenarios to influence selection on appropriate materials, topology, materials, network layouts, lightning schemes etc.
- Inform new lightning protection standards based on how future lightning types, distributions, probabilities compare with existing standards such as BS EN 62305.

Consumer Vulnerability Impact Assessment

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been carried out using a bespoke assessment tool, which assesses the project as having a positive, negative or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register.

This project has been assessed as having an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to enhance network resilience, least cost decision making, transmission capability and operability that will ultimately reduce exposure costs for households.

Success Criteria

This project is deemed as successful if its stated objectives are achieved.

Project Partners and External Funding

N/A

Potential for New Learning

The potential new learnings from this project are already embedded in the project objectives and will emanate from a greater part of the scope which involves chartering in novel research territories.

The learning will be disseminated through the publication of project progress and closedown reports on the ENA portal. Various workshops and dissemination events are planned. Weather resilience has been discussed in general under ENA members as a topic that the networks might want to start a working group on to ensure alignment as there is lots of work in this area. A form of combined roadmap for weather resilience across networks is envisioned that will coordinate usage/sharing of common tool(s).

Scale of Project

This project is planned to take 18 months. The scale of the project is already exhibited in the scope in section 2.3.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL7 Inactive Commissioning

Geographical Area

The work will be undertaken at/by University of Bath, aimed to understand lightning impact on UK electricity infrastructure even from satellite sources, and data collection activities can extend to any identified NGET substations including Deeside Centre for Innovation. The project will review the experiences and solutions of other countries that are lightning hotspots, such as Africa and North America. This will ensure use of the latest data and models and avoid duplications. University of Bath will use visiting privileges to South Africa and exploit the network to access relevant lightning data.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£478,656.00

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

During the transition, energy systems have to remain resilient to various natural disasters, particularly climatological events. Lightning strike patterns are evolving with climate change pausing severe outage risk.
This project aims to study how lightning will change in the future and how lightning strikes will impact UK transmission network infrastructure, by connecting data from multiple domains and applying novel deep learning for data fusion and pattern recognition.
It will provide better knowledge and tools for managing and planning the energy system more resilient and robust against lightning risks, thus facilitating a secure energy system transition.

How the Project has potential to benefit consumer in vulnerable situations:

N/A

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved

N/A

Please provide a calculation and/or description of the expected benefits of the solution

The new solutions would help with the effective planning and operation of electricity networks against lightning strikes, which could cause asset damage and outages.

A 2019 outage caused interruptions to over 1.15 million consumers' electricity supply and several other services were disrupted due to the affected service. The economic cost was estimated to be over 15 million. Although the likelihood of lightning strikes causing big outages is very low, the impact could be dramatically high. As the electricity system is becoming much more complicated and the climate changes at an unprecedented pace, the value of the loss in future could be much higher.
It is proposed that the development of new knowledge and platform would help mitigate the financial impact of £15 million by reducing potential outages.

The potential benefits include:
• A robust energy system against lightning strikes, with reduced outages and interruptions
• Reduced asset failure and maintenance costs
• Reduced labour hours to repair and restore
• Informed new planning standards for the energy systems
• Regulatory compliance to plan and operate better energy systems for society

Please provide an estimate of how replicable the Method is across GB

The solution developed is replicable across GB depending on the amount of related operational/infrastructure data networks hold.

Please provide an outline of the costs of rolling out the Method across GB.

If the method developed in the project is successful, the detailed costs of rolling out the method will be assessed and outlined following project closure.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

Involve Research, Development or Demonstration - Please select all that apply

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☑ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☑ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Learning from this project will include a deeper understanding of the risks that lightning strikes may have on critical infrastructure operated and maintained by NGET. The knowledge, findings, and flexible QGIS-based platform can also be beneficial to other electricity networks.

N/A

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed. Networks must explicitly mention similar projects that they have considered and how these differ.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

There is no project on the ENA website that matches the scope and objectives of this project. Storm Resilience project (NIA_UKPN0053, Dec 2019 – Dec 2021) studied the impact of lightning focused on distribution networks and real-time fault management, offering limited insights for transmission network planning.
KERAUnIC combines the complementary expertise of power engineering and lightning science to create novel solutions that can inform more robust and resilient electricity whole system network planning and operation.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

N/A

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

It is the first time to systematically study potential lightning threats to transmission networks under climate change and uncertain network development. The project will use the latest lightning data that has never ever been available before for more accurate lightning strike modelling. The project will also fuse data from various sources to map the development of UK electricity network infrastructure under different energy scenarios.

Commercially, the solution is yet to be fully adopted by the stakeholders as it has not reached the level of maturity required for business-as-usual applications. This risk will be mitigated by early engagement with stakeholders and ensuring requirements are clearly defined and documented.
Operational risk manifests in very limited data available for accurate lightning and electricity infrastructure mapping. This will be mitigated by adopting advanced machine learning for small data and multi-source data fusion.
If the project is successful, it will have introduced proven technical solutions that will improve energy supply security.

Through cross-disciplinary work, this project encompasses the following innovations:

- Previous NIA and innovation projects were mainly focused on the risks of other climatological variables and man-made events, such as strong wind, extreme temperature, and cyber-attacks. It will be the first time to systematically study potential lightning threats to transmission networks under climate change and uncertain network developments.
- Use of latest lightning data that was unavailable before for more accurate lightning modelling. Combining diverse sources of data and using novel machine learning will enable the project produce more accurate predictions of lightning strikes and move away/overcome/challenge the assumptions that tie future lightning strikes with historical patterns.
- Generate deep knowledge relating lightning strikes and network assets. It will interface with existing systems to reinforce or give a more representative/reliable electricity infrastructure/lightning map.
- Develop an agile and flexible QGIS-based platform/equivalent to visualise the results and offer the capability to pinpoint vulnerable areas/hotpots and navigate through different future energy pathways/scenarios.

Relevant Foreground IPR

All IPR is governed by the “National Grid Standard RIIO-2 Contracting Position – JOINT IP OWNERSHIP” that sets out National Grid’s standard approach to Network Innovation Allowance (NIA) funded projects under the RIIO-2 framework. The Foreground IPR shall be owned jointly between the Parties in equal shares.

Foreground IPR will be created in the form of forecasting, models, mapping and the QGIS platform.

The suppliers will contribute to the background IPR in terms of knowledge, knowhow, software and data relating to:

- Comprehensive understanding of storm-related hazards.
- Modelling thunderstorms and various lightning.
- Modelling energy systems.
- Modelling robustness of energy system asset.
- Machine learning algorithms and knowledge.
- Fragility of network assets.
- Secure cloud storage and handling of sensitive data.
- Integrations of data from a large number of sources.
- Experience in visualising environmental risks and asset vulnerability.
- QGIS platform for visualising data and risks.

NGET will contribute background IPR in the form of knowledge and data relevant to its operation across the electricity transmission network in England and Wales.

The default IPR position will be applied to this project.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click

‘Contact Lead Network’. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.

- Via our Innovation website at https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

Please identify why the Network Licensees will not fund the project as a part of it's business and usual activities

The proposed solution is innovative in nature, with a component level of risk that is unsuitable to Business as Usual (BaU) implementation straightaway and thus BaU is not the appropriate funding mechanism for this project.

The project aims to combine and utilise complex data sets related to assets, environment, and weather, and it will also combine expertise in power engineering and lightning science. The techniques are yet to be proven in the utility network but are ambitious and novel.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks (e.g. commercial, technical, operational or regulatory) associated with the project

The project settles in to get support of NIA, in a fully controlled environment where there is no risk of causing network disruptions/outages while surveys and investigations could also be safely developed. Therefore, NIA, rather than BaU, is the appropriate funding mechanism for this project.

The project can only be undertaken as an innovation pilot given the risks associated with the development of an unproven solution for network operations. Progressing using NIA funding ensures the outcomes of the project are shared with other network licensees, allowing them to adopt similar practices.

This project has been approved by a senior member of staff

☑ Yes