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## NIA Project Registration and PEA Document

### Date of Submission

Apr 2024

### Project Reference Number

NGED\_NIA\_075

## Project Registration

### Project Title

LCT Harmonic Limits

### Project Reference Number

NGED\_NIA\_075

### Project Licensee(s)

National Grid Electricity Distribution

### Project Start

May 2024

### Project Duration

1 year and 1 month

### Nominated Project Contact(s)

Jacob Lynch

### Project Budget

£187,808.00

## Summary

The LCT Harmonic Limits project will undertake desktop research and investigate how many Electric Vehicles (EVs) and Heat Pumps (HPs) can be connected to an LV network prior to harmonic violations being exceeded. This project will model both urban and rural networks, consider the background emissions that are already in existence and also consider varying diversities of LCTs in terms of percentage of EV against HP and also the distribution of LCTs along a given feeder.

The outcome of the project will aim to enhance our current design processes and standard techniques that focus on the minimum and maximum source impedance requirements before intervention is needed. Updating these standards will give greater confidence in our network and also result in quicker connections to customers.

## Problem Being Solved

With the energy transition to Net Zero being well underway, the move to Low Carbon Technologies (LCTs) for domestic customers is continually on the rise, creating a significant increase in electricity consumption among other potential issues. One of these additional issues is the power quality of the distribution network.

Power quality is the degree to which the voltage, current and frequency of a waveform on the electricity network conform to established standards and specifications. Voltage that is steady and kept within a prescribed range can be classed as good power quality. However, when multiple LCTs, in the form of Electric Vehicles (EVs), Heat Pumps (HPs) and to an extent Battery Energy Storage Systems (BESS) amongst other loads (such as arc furnaces and rectifiers) are connected to the distribution network, the power quality can be disturbed and reduced through the creation and existence of harmonics.

Harmonics are voltage and current sinusoidal waveforms that exist where its frequency are integer values above the fundamental frequency (50Hz). These harmonic frequencies are created due to the aforementioned LCTs being classed as non-linear loads, mainly due to rectifiers and switching from AC to DC within them. The harmonics result in disturbing and modifying the pure 50Hz sinusoid waveform resulting in potential degradation of network assets, mal operation and thermal issues.

Knowing this, DNOs must be aware of the potential effects of connecting too many LCTs on a single feeder. Having said that, a DNO

cannot and will not want to be a barrier in the energy transition in blocking the uptake of LCTs.

The LCT Harmonic Limits project proposes to undertake desktop research and investigate specifically how many EVs and HPs can be connected to a network prior to harmonic violations being exceeded. This piece will detail various networks that are present in urban and rural areas of the National Grid geographic, consider the background emissions that are already in existence and also consider varying diversities of LCTs in terms of percentage of EV against HP and also the distribution of LCTs along a given feeder.

## Method(s)

In 2016, National Grid Electricity Distribution (NGED), formerly Western Power Distribution (WPD), undertook a Network Innovation Allowance (NIA) project that sought to identify the 'emissions' that are generated through the charging cycle of Electric Vehicles. These emissions came in the form of generated harmonics over a range of vehicle manufacturers that were captured at the Millbrook testing facility.

Although the project led to the creation of WPD / NGED standard techniques and policy, these documents do not account for the inclusion of heat pumps and other LCTs in addition to differing geographical networks such as those seen in an urban and rural environment.

The purpose of the LCT Harmonics project will be to refine and further explore this area by calculating the maximum number of electric vehicles and heat pumps that can be connected to the network before harmonic limits are exceeded. This will include both rural and urban models and will contain analysis for various proportions of LCTs and placements along the feeder of the network.

The LCT Harmonic Limits Project will build upon the findings of the Electric Vehicle Emission project, and provide maximum connection information for both EV's and HP's combined. Specifically, the maximum number of EV and HP that can be connected on a model-rural and model-urban network will be determined, with the process exploring the sensitivity of the results to:

- Clustering of EV and HP along the feeder. As per the previous study, there will be an investigation into a random distribution and an evenly spread distribution of LCT along the feeder.
- Different proportions of EV and HP within the overall LCT penetration. This will study the effect of differing percentages of EV compared to HP to understand the network impact depending on the weighting of a certain LCT.
- Background emissions already existing on the network.
- Variation of charging diversity. Economy 7 tariffs were traditionally used in the past for EV charging but current ToU tariffs offer shorter charging windows resulting in more frequent charging per week for a customer.
- The simultaneous harmonic current export from the LCT connected to the feeder based on nominated assumptions about the time of day behaviour of the EV and HP at that particular time of day.
- The effect of local BESS will also be considered.

## Measurement Quality Statement

Measurement quality will form a key part of the analysis. Monitoring devices that will be used are ones that are currently used in standard practice. Multiple devices will be used to validate further and give a greater confidence level. Developed outputs and deliverables will go through multiple rounds of review to ensure the correct process has been followed.

## Data Quality Statement

Data will be captured at through standard LV monitoring during this project. This will be processed and stored using our standard policies and procedures. Data associated with harmonics generated via HPs and EVs will be redacted prior to publishing.

## Scope

The scope of LCT Harmonic Limits is to understand the maximum number of LCT connections that can be made to an individual rural and urban LV network before harmonic violations are exceeded. Through network modelling and power systems studies, our current policies and procedures relating to the connection of LCTs can be updated, and our insights and assumptions towards the network will be more robust and clear-cut. This will undoubtedly result in faster connections being made associated with LCTs at a domestic scale and create greater security with our network due to improved policies.

The project will be able to directly create benefits through providing more robust assumptions and procedures and further our understanding of how many LCTs can be connected to a single feeder. In doing so, this will result in less harmonic assessments having to be carried out by network planners creating a labour saving benefit. By not having to carry out harmonic assessments prior to connection, an additional benefit will be that this process will speed up the connection process for a range of LCTs at the domestic

scale. This is something quite prudent as the take up of domestic LCTs is only going to increase over the coming price controls.

## Objective(s)

- Comprehensive network studies are carried out that identify the maximum number of LCTs that can be connected to an urban LV network during winter and summer periods.
- Comprehensive network studies are carried out that identify the maximum number of LCTs that can be connected to a rural LV network during winter and summer periods.
- Capture sufficient background harmonic measurements from real life networks
- Determine the Maximum and Minimum allowable source impedance
- Outputs of deliverables inform and update current NGED design practices and policies.

## Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

This project has the potential to speed up the connection of LCTs to domestic customers in addition to reducing time spent on carrying out harmonic assessments. The underlying benefits will reach all customers through efficiency savings of the DNO and faster connection processes. Therefore, if all customers will reap benefit, those that have identified vulnerabilities will also benefit.

## Success Criteria

The Project will be deemed successful if the following outcomes are achieved:

- Rural and Urban Models designed that are an accurate representation of those seen on NGEDs network.
- Comprehensive network studies are carried out that identify the maximum number of diversified LCTs that can be connected to an urban LV network during winter and summer periods.
- Comprehensive network studies are carried out that identify the maximum number of diversified LCTs that can be connected to a rural LV network during winter and summer periods.
- Maximum and Minimum source impedance identified.
- Outputs of deliverables inform and update current NGED design practices and policies.

## Project Partners and External Funding

### Project Partners:

#### National Grid:

National Grid Electricity Distribution have a proven track record of delivering successful innovation projects that influence strategy and change DNO policy. We are always looking for ways to develop our innovation strategy to ensure we prioritise the most critical areas, aiming to be capability driven. The Innovation Team have robust project management governance and business engagement, to ensure successful delivery of projects like this.

National Grid will:

- Coordinate the project and ensure delivery is to the objectives specified in this report
- Provide relevant data and information regarding background harmonic emissions
- Complete project closedown and dissemination activities

#### EA Technology Ltd:

EA Technology Ltd are an experienced Electrical Engineering Consultancy, with a specialism working for Distribution Network Operators. They have a strong track record of delivering similar work, such as our SILVERSMITH project, using the same toolsets as this project utilises.

EA Technology Ltd will:

- Lead network modelling and carry out harmonic studies
- Present findings in numerous stage reports
- EA Technology Ltd are providing a financial contribution of £10,200 to the project

## Potential for New Learning

The learning generated from undertaking this project will strive towards updating our policies and procedures behind the connection of LCTs at the LV network. Existing policies have been authored on the basis of previous innovation projects and subsequently need to be re worked due to the inclusion of HPs and other LCTs, evolving market conditions such as ToU tariffs which will effect charging assumptions and additional analysis that will give updated insight into the network impact such as spread along the feeder, seasonal conditions and proportion of LCT over another.

The learning generated will also be able to feed in to other wider standards within the industry that includes other DNOs and ENA.

## Scale of Project

The project is desktop only. The associated reports and network analysis studies will be produced.

## Technology Readiness at Start

TRL4 Bench Scale Research

## Technology Readiness at End

TRL8 Active Commissioning

## Geographical Area

The project is primarily desktop only. Models will be created that represent NGED networks from a rural and urban setting. In the case of obtaining background emissions, LV monitors will be installed across a few areas within the NGED license area.

## Revenue Allowed for the RIIO Settlement

None

## Indicative Total NIA Project Expenditure

Total Project Cost: £187,808.20

Agreed Partner Contributions: £10,200

Sub Total: £177,608.20

National Grid DNO Contribution: £17,760.82

Funding from NIA: £159,847.38

## Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

### Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

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

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

The energy system transition relies on rapid uptake of LCTs that include heat pumps and electric vehicles in order to reach net zero in a timely fashion. Carrying out studies that calculates the maximum number of heat pumps and electric vehicles that can be connected to the network prior to harmonic limits being exceeded will undoubtedly increase the connection process for domestic LCTs due to the added assurance the network operator has as a result from this project.

#### 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 (RIIO-1 projects only)

The project has to the potential to offer cost savings through reduced labour spent carrying out harmonic assessments due to the forecasted uptake of LCT connections being made downstream of ground mounted and pad mounted substations. This would be the case if insufficient knowledge is known about the network, however, by investing in this project, greater network insights will be obtained resulting in less harmonic assessments to be made. This results in a potential yearly saving of £393,000.

#### Please provide a calculation of the expected benefits the Solution

It is common knowledge that we foresee a significant increase in LCT connections surrounding EVs, HPs and BESS within this time period and in doing so, due to the harmonic output that they provide, they may require some form of harmonic assessment from NGED prior to the network being confident the connecting asset will not cause non-conforming issues.

Carrying out these assessments can be a time consuming process, and having a process that allows these assessments to be reduced will inevitably increase staff cost savings. The following page highlights the high level assumptions and information used to inform the potential financial benefits LCT harmonic Limits will bring.

These assumptions are:

- The number of NGED Pole Mounted Transformers (PMT) is 58,000
- The number of NGED Ground Mounted Transformers (GMT) is 127,000
- Harmonic assessment is needed for at least 50% of these sites
- Time take for harmonic assessment is between ½ day to 1 day
- Day rate for assessment is network service day rate of £445
- Assume inflation rate for assessment of 2.5%
- LCT Harmonic Limits process allows 35% reduction of assessments

Spreading out the total number of sites (185,000) over a 16 year period (2024-2040, End of ED4) results in a total number of 11,562 assessments needed to be carried out per year out to the end of RIIO-ED4 (not including additional PMT and GMT that will exist in that

time period). As stated in the assumptions, a conservative minimum 50% of sites will need some form of harmonic assessment with the taken for between ½ day and 1 day. The bullet points below outlines the labour cost to carry out assessment based on number of sites and duration it takes.

- 50% of sites, ½ day assessment (£1.29m / year)
- 80% of sites, ½ day assessment (£2.06 / year)
- 100% of sites, ½ day assessment (£2.57m / year)
- 50% of sites, 1 day assessment (£2.57m / year)
- 80% of sites, 1 day assessment (£4.12m / year)
- 100% of sites, 1 day assessment (£5.15m / year)

Based of the above calculations, the below table highlights the baseline costs assessments have to NGED out to the end of the ED4 price control period (2040).

- 50% of sites, ½ day assessment yielding a summated cost of £26.8m out until 2040
- 80% of sites, ½ day assessment yielding a summated cost of £42.9m out until 2040
- 50% of sites, 1 day assessment yielding a summated cost of £53.7m out until 2040

Having established the baseline figures, it is worthwhile understanding the proposed counterfactual in order to understand the underlying benefits the LCT Harmonic limits project brings. The assumption is that with the LCT Harmonics process in place, the reduction of assessments carried out will be 35% less than the base case. Applying this information to the calculations above, it yields updating costings that will be spent by NGED on carrying out harmonic assessments.

- 50% of sites, ½ day assessment yielding a summated cost of £17.4m out until 2040
- 80% of sites, ½ day assessment yielding a summated cost of £27.9m out until 2040
- 50% of sites, 1 day assessment yielding a summated cost of £34.9m out until 2040

Annually, the benefits are estimated to be between £390k-£790k, over the ED2 period between £1.56m-£3.15m and out to 2040, between £6.30m-£12.6m.

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

The output of this project will be relevant for all GB electricity network operators and can be implemented with no additional work.

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

As the project is a research piece relevant to all GB electricity network operators, no costs apply to rolling the project out.

### **Requirement 3 / 1**

Involve Research, Development or Demonstration

A RIIO-1 NIA Project 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

RIIO-2 Projects

- 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

This project will carrying out detailed network studies focussing on the maximum amount of heat pumps and electric vehicles that can be connected to a rural and urban network prior to harmonic limitations being exceeded. The learning generated, through deliverables should be easily digestible and transferable to other DNOs as their process are likely to be similar.

### Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

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.

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

The methodology for this project has been reviewed against other projects registered on the Smarter Networks Portal and circulated with other DNOs and TNOs ahead of registration to ensure no unnecessary duplications will occur

### 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

Although studies have been carried out around the impact of EVs on the electricity network, no study has been carried out in detail that aims to understand the harmonic impact that can be observed on the electricity network when a range of LCT connections are made at the domestic LV level. Currently, there is a risk of our current assumptions and procedures will be become dated due to the ever changing energy landscape. Therefore, we need new innovative techniques introduced into the analysis in order the required learning that will update our policies and have better assumptions and knowledge of our network. These updated procedures that will ultimately be put in place within our organisation, will be able to also be shared with other network operators so that they can benefit from the learning generated from this project.

### Relevant Foreground IPR

The Relevant Foreground IPR is:

- All deliverable reports and documents produced during the project delivery
- Rural and Urban LV network models

The Relevant Background IPR required to produce this is:

- National Grid's network modelling data

### Data Access Details

All project findings will be published on the Smarter Network Portal, and on National Grid's website.

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

We would not be able to fund this type of investigative work as a BAU activity. The new methodology is not proven and there are elements to the analysis that haven't been tested or proven .

**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 NIA funding is seen as necessary due to the unproven methodology of calculating the maximum number of LCTs that can be connected to a network prior to harmonic limits being exceeded. The need to build sufficient rural and urban models that are representative to cover a range of ones seen on NGEDs network is seen as a risk which can only be supported via the NIA. We would not undertake this project without NIA funding as the technology readiness level (TRL) would be too low.

**This project has been approved by a senior member of staff**

Yes