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.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Close Down Report Document

Date of Submission

Jul 2023

Project Reference Number

NIA2_NGESO006

Project Progress

Project Title

Resilient Electric Vehicle Charging: “REV”

Project Reference Number

NIA2_NGESO006

Project Start Date

July 2021

Project Duration

1 year and 6 months

Nominated Project Contact(s)

Annu Tiwari

Scope

- The project will analyse the impact of EV charging on grid short term frequency and voltage stability, and cascade fault prevention and recovery.
- An individual charger has a small impact on the grid. So, the analysis will therefore focus on categories of failures which could cause a correlated change by multiple chargers at the same time and/or local area.
- Brainstorming sessions with multiple stakeholders will be employed to identify the widest possible range of risks.
- EV charger response to power and control communication faults will be investigated by desk-based research and sample measurement.
- Identified risks will analysed in via desk research. From this a prioritised list of risks, in the form of an FMEA (Failure Mode Effect Analysis), will be produced for further investigation.
- Small scale grid simulation studies will be used to address uncertainties in the desk-based analysis.

Objectives

The final outputs will be:

- A research report on potential causes of instability
- A research report on the effects of instability (NIA Project Completion Report)

Success Criteria

The following will be considered when assessing whether the project is successful:

- Identification of one or more “black swan” risks
- Impact on ESO risk management processes related to EV and DSR
- Contribution to behind the meter DSR regulation processes
- The estimate potential financial benefit of EV DSR by 2030

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Project Overview

Decarbonisation of the economy will drive a transformation of the GB power system beyond that already caused by the growth in renewable energy.

By around 2040

- peak demand is forecast to increase by 50% in all Future Energy Scenarios.
- demand for energy will at least double over the same time period in three out of four scenarios.

Much of this new demand will come from "smart" loads, controlled by software systems, whose behaviour will be very different to traditional system demand. Just as inverter-connected generation has brought new challenges for grid operation, the presence of these new types of smart load will introduce system risks that have not been seen before.

Project REV is investigating what these risks might be for one rapidly growing group of technologies, Electric Vehicle Charging (EVC) and Vehicle-to-Grid generation (V2G).

Project Plan

The project consisted of two work packages:

Work Package 1 (WP1) – Cause (How could EV charging make the grid less stable?)
Identify the mechanisms which may impact short term grid stability and recovery from incidents.

Work Package 2 (WP2) - Effect (How big could the impact be on the grid as EV adoption increases?)
Model the impact on UK wide grid stability.

Project Activities

WP1: Cause (How could EV charging make the grid less stable?)

The initial phase of WP1 consisted of a series of brainstorming sessions with industry experts with the objective of identifying as many ways as possible that EV charging could make the grid less stable. These sessions took the format of a technical introduction to the specific subject being discussed, follow by a structured brainstorm. Topics covered included:

- Power quality supplied to the charger
- Impact of power quality on the EV charger power converter, control, and protection systems
- Impact of the EV charger population on grid stability and operability
- Communication and control system inputs to the charger including market signals and aggregation
- Impact of the external control system, time, and cyber threats within the charger and on the grid

Each topic was explored from a wide range of stakeholder perspectives including Consumer, Distribution Network Operator, System Operator, Energy Supplier, ChargePoint Operator, Aggregator, Hacker, OEM, Communication Systems Operator.

Over 100 issues were identified in the brainstorming sessions. These were initially loosely grouped for analysis. The team then confirmed each issue was technically plausible and large enough to have a significant impact on grid stability. Tasks included:

- Confirming the technical viability of the mechanism;
- Identifying if similar issues had been encountered before with other technologies or in different regions around the world;
- Assessing appropriate impact thresholds which apply to the GB grid and estimating the number of EVs required to have a significant impact on the grid;
- Testing the fault ride-through performance of a sample EV smart charger to confirm hypothesised performance, including degradation of both power supply and communication links.

Our analysis then focused on issues which, if they were to remain unmitigated, could lead to power outages. This resulted in the grouping under topic headings in the WP1 report: “Six ways in which Electric Vehicle chargers present a risk to grid security” (available on the Smarter Networks Portal) The report dissemination was supported by a webinar with Q&A.

WP2: Effect (How big could the impact be on the grid as EV adoption increases?)

WP2 analysed a number of specific mechanisms by which Electric Vehicle chargers could present a risk to grid security.

A range of grid simulation studies were used to expand on the analysis from WP1. These studies are using the ESO full system model, known as the Off-Line Transmission Analysis (OLTA) model. This modelling allows consideration of wide area effects such as Voltage Stability, Transient Stability and Oscillatory stability.

Analysis of the measurement data from the grid during normal and anomalous operation was also conducted. This includes:

- The impact of power steps related to time-of-use tariffs on grid frequency and the related balancing actions required to maintain operation within regulatory limits.
- Typical voltages in the LV network seen by EV chargers and the impact on fault ride-through

The analysis highlighted the limitations of current load modelling within grid analysis tools. Load response is becoming more complex as we move from directly connected loads to far greater use of power converters and software control systems.

We also expanded on the WP1 analysis of the impact of mass EV and V2G adoption on OC6 demand control and the restoration process.

During WP2 we estimated the potential financial benefit that EV Demand Side Response(DSR) could provide by 2030, highlighting that smart charging, as opposed to unmanaged charging, has the potential to reduce costs for consumers. Project REV has highlighted a wide range of potential issues that could arise from mass adoption of smart EV charging and V2G. The aim of the project is to help address these issues before they have a detrimental impact within the GB grid and ensure that the benefits of smart charging can be realised, without major downsides.

Alongside the core WP2 activities the project REV team have also been sharing knowledge gained within the project in discussions with a range of teams within ESO, several DNOs, the ENA and internationally.

Required Modifications to the Planned Approach During the Course of the Project

The project has proceeded in line with the general concept of the original plan. However, the breadth of the issues identified in WP1 and the complex nature of some, exceeded initial expectations.

Involving a wide range of experts in WP1 brainstorming was very helpful, however most tended to have expertise in their specific domain and none had prior familiarity with all topics discussed. To support wide-ranging analysis of the issues, a significant proportion of each brainstorming sessions had to be given over to training, to ensure a shared understanding of the topics under discussion, allowing wide-ranging informed debate. This was reflected through to the WP1 report, which also aims to provide relatively simple explanations of topics for those outside the specific domains.

The complete EV DSR system architecture is both complex and rapidly evolving, from products and services to market structures and other regulations. As a result, the initial concept of undertaking a detailed Failure Modes & Effects Analysis within WP1 was dropped in favor of a simple, accessible presentation of a scale of Red, Amber or Green (RAG) risks which was more appropriate to the fluid evolving market.

The wide number of issues identified in WP1 resulted in the need to prioritise activities in WP2. Emphasis was placed on topics where there was the greatest level of uncertainty and where simulation studies were viable within the scope of available modeling capabilities and the project timeline.

During WP2 significant effort was put into contributing to ongoing regulatory activity to maximize the immediate benefits from the project. Many of the topics raised within Project REV are unfamiliar within the industry. Extensive communication with multiple parties was carried out throught WP2.

Lessons Learnt for Future Projects

Project REV has been a first of its kind analysis of the potential impact of EVs on GB grid stability. It has identified a very wide range of issues and highlighted both the speed and the scale of the change which will occur over the next few years.

The challenge for future related projects is to address these issues, while learning from lessons identified within Project REV.

- Smart charging is a complex, rapidly evolving system of systems; knowledge sharing across technology domains is important to aid development of solutions enhancing resilience. A wide range of expertise was brought together, including transmission and distribution systems, communications, home energy systems and vehicle electronics design; this experience was then supplemented with contributions from a wide range of invited experts. This breadth of knowledge was essential to identify risks in this emerging and complex environment.
- There are a wide range of stakeholders, whose objectives are not naturally well aligned.
- Short term fixes can have unintended longer-term consequences, for example the German 50.2Hz problem mentioned in the WP1 report.
- Retrospective changes can be very slow and expensive to implement, for example the Accelerated Loss of Mains Change Program mentioned in the WP1 report.
- Setting up the capability to carry out simulation studies using OLTA was anticipated to be challenging. Even though a generous allowance was made for this in the project timeline, the capability still came online later than planned.
- OLTA study processes are highly customized to NGESO business practices and the GB network, and Project REV benefitted greatly from access to an experienced OLTA user.

Acting on the report's findings will require concerted effort involving a broad range of stakeholders.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

Identification of one or more "black swan" risks

The WP1 brainstorming activity identified a number of risks which were not well known or understood within the industry. These have been documented in the WP1 report and described in a webinar which was used to further raise awareness. A subset of these risks were simulated to assess the severity of the impact and results are presented in the WP2 report.

Contribution to behind the meter DSR regulation processes

The Project REV WP1 report is already proving influential. In a BEIS consultation "Delivering a smart and secure electricity system: the interoperability and cyber security of energy smart appliances and remote load control", Question 9 on Grid Stability quotes and draws heavily on the findings of WP1.

Delivering a smart and secure electricity system: the interoperability and cyber security of energy smart appliances and remote load control - GOV.UK (www.gov.uk)

Findings from WP2 have been shared with the DESNZ Smart and Secure Energy Appliance Team contributing to the potential future development of the smart ChargePoint regulations and the energy smart appliance standards.

Project REV is thus contributing to behind the meter DSR regulation processes and its influence will go beyond EVs to include other DSR appliances such as heat pumps.

Impact on ESO risk management processes related to EV and DSR

The finding from Project REV are highlighted on page 85 of the recent ESO Operability Strategy Report (https://www.nationalgrideso.com/document/273801/download). This raised awareness of the issues identified in the ESO and wider industry. Project REV team members also contributed to the Frequency Risk and Control Report consultation process.

Project REV is also having a direct impact on the Grid Code working groups used by the industry to address emerging risks.

Knowledge generated in the project has contributed to the following groups:

- GC0151 & GC0155 Fault Ride-Through
- GC0154 Interconnector Ramping
- GC0148 & GC0156 Restoration

Project REV findings are also being shared with the Energy Networks Association to assist in future development of Engineering Recommendation G99 (Requirements for the connection of generation equipment in parallel with public distribution networks).

More broadly, the Project REV reports has been shared and received with interest by international organisations including:

- Global Power Systems Transformation Consortia
- Electric Power Research Institute
- National Electric Reliability Corporation
- Western Electricity Coordinating Council
- Australian Energy Markets Operator
- Energy Queensland

Project REV findings are contributing to a group defining a "Grid Friendly EV Charging Recommendations" which highlights how EV charges response to disturbances will become critical to grid operability.

Learning from the project has also been shared cross-sector, for example via the Safety Critical Systems Club, which is the UK's professional network for sharing knowledge about system safety.

The estimated potential financial benefit of EV DSR by 2030

The WP2 report provides the estimate that smart charging benefits are likely to reach £400m per year by 2030. Key to achieving this benefit is addressing the risks identified with Project REV as early as possible.

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available "Data sharing policy related to NIC/NIA projects" and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA/SIF projects on the Smarter Networks Portal (www.smarternetworks.org) and National Grid ESO Data Portal (data.nationalgrideso.com). You may wish to check these websites before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

The following Foreground IPR is expected to be generated from this project:

- A research report on potential causes of instability
- A research report on the effects of instability (NIA Project Completion Report)

The reports produced in the course of the project have been made available on the Smarter Networks Portal.

Planned Implementation

The WP2 report (pg 75) contains a series of recommendations to the industry as a whole. The report also contains the list of specific recommendations for the ESO, which is highlighted below.

RoCoF and vector shift 1

1. Grid operators need to allow margin for variations in regional RoCoF and in product RoCoF algorithm performance, for normal operation and during restoration. Use of the full 1 Hz/s RoCoF range should be avoided.
2. Vector shift fault ride-through to be specified in regulations. For example, via GC0155 3.
3. Implement improved grid RoCoF (and vector shift) monitoring and data sharing going beyond GC0105/GC0151

Under and over voltage 1

1. Recognise and actively manage the risks associated with mass coincident tripping of LCT due to under- or over-voltage as adoption increases.

2. Consider the risk to grid stability from coincident tripping of LCT as part of the assessment of the proposed voltage limit change.
3. Implement improved time resolution for grid LV monitoring so it can identify the risks of coincident tripping of fast LCT voltage protection.

Stability Analysis

1. Develop enhanced load models to improve the accuracy of stability simulations which recognize the significant change in load relief.
2. Investigate how best to include the impact of LCT protection systems in stability studies.
3. Assess the potential impact of mass smart system controlled LCT on OC6 demand control and cold load pick-up and mitigate the risk.
4. Exploit the ways in which ECV, V2G and other LCT can enhance voltage control

Realising the benefits

1. Investigate the potential growth of load steps on the half-hourly settlement period boundaries and mechanisms to predict, manage and mitigate the associated risks.
2. Address issues with the resilience of DSR, recognizing its potential impact in enhancing or degrading the resilience of critical national infrastructure.
3. Maximise the value from smart charging and V2G by using these assets to provide grid support services, not just time-shifting of energy

A final recommendation is to encourage wider participation in grid code, and other regulatory working groups, especially from aggregators involved in the controls of smart energy appliances, including EVs.

Next steps

- The ESO will continue to raise awareness of the challenges of mass EV adoptions, through BAU, including documents such as the operability strategy report and ongoing regulatory processes.
- This will lead to further engagement with EV and ChargePoint manufactures, aggregators and DNOs/DSOs to address the risks identified in Project REV.
- Innovation projects to address some specific challenges identified in Project REV are under consideration. This includes issues described in problem statements at the recent 2023 Strategic Innovation Fund basecamp event.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report ("Viewer") require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

Standards Documents

No new standards documents have been developed within Project REV, butthe project outputs are influening a wide range of regulations,standards and recommendations including:

- BEIS/DESNZ Smart Secure Electricity system activities and related legislation or Statutory Instruments
- National Grid ESO Grid Code
- Energy Networks Association G99 and distribution code
- British Standards Institute Energy Smart Appliance Activity
- NERC/CMC/WECC Grid Friendly EV Charging Recommendations