WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

Vehicle to Grid
Electric Nation

Report Title	:	Electric Nation: Vehicle to Grid Report
Report Status	:	Final
Project Ref	:	WPD NIA 013 – Electric Nation
Date	:	27.11.17

Document Control

	Name	Date
Prepared by:	Nick Storer	27.11.2017
Reviewed by:	Gill Nowell	27.11.2017
Approved (WPD):	Mark Dale	27.11.17

Revision History

Date	Issue	Status
25.10.2017	1	Draft
16.11.2017	2	For internal review
27.11.17	3	Final

Contents

DISCLAIMER
Neither WPD, nor any person acting on its behalf, makes any warranty, express or implied, with respect to the use of any information, method or process disclosed in this document or that such use may not infringe the rights of any third party or assumes any liabilities with respect to the use of, or for damage resulting in any way from the use of, any information, apparatus, method or process disclosed in the document.

© Western Power Distribution 2017
No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means electronic, mechanical, photocopying, recording or otherwise, without the written permission of the Future Networks Manager, Western Power Distribution, Herald Way, Pegasus Business Park, Castle Donington. DE74 2TU. Telephone +44 (0) 1332 827446. E-mail WPDInnovation@westernpower.co.uk

Glossary

Abbreviation	Term
EV	Electric Vehicle
OEM	(EV) original equipment manufacturer (e.g. Nissan, Tesla)
OCPP	Open Charge Point Protocol
PHEV	Plug in Hybrid vehicle
V2G	Vehicle to Grid

1 Introduction

1.1 Electric Nation

Electric Nation is a Western Power Distribution and Network Innovation Allowance funded project. WPD's collaboration partners in the project are EA Technology, DriveElectric, Lucy Electric GridKey and TRL.

Electric Nation, the world's largest electric vehicle (EV) trial, is revolutionising domestic plug-in vehicle charging. By engaging 500-700 plug-in vehicle drivers in trials, the project is answering the challenge that when local electricity networks have 40% - 70% of households with electric vehicles, at least 32% of these networks across Britain will require intervention.

The project is developing and delivering a number of managed EV charging solutions to support plug-in vehicle uptake on local electricity networks. A key outcome will be a tool that analyses plug-in vehicle related stress issues on networks and identifies the best economic solution. This 'sliding scale' of interventions will range from doing nothing to managed EV charging, from taking energy from vehicles and putting it back into the grid, to traditional reinforcement of the local electricity network where there is no viable "smart" solution.

The development of the project deliverables is being informed by a large-scale trial involving plug-in vehicle drivers that will:

- Expand current understanding of the demand impact of EV charging at home on electricity distribution networks of a diverse range of plug-in electric vehicles - with charge rates of up to 7kW+, and a range of battery sizes from 10kWh to 80kWh+.
- Build a better understanding of how vehicle usage affects EV charging behaviour.
- Evaluate the reliability and acceptability to EV owners of managed EV charging systems and the influence these have on EV charging behaviour. This will help to answer such questions as:
    - Would charging restrictions be acceptable to customers?
    - Can customer preference be incorporated into the system?
    - Is some form of incentive required?
    - Is such a system perceived as being 'fair'?
    - Can such a system work?

The results of this project will be of interest and will be communicated to the GB energy/utility community, UK government, the automotive and plug-in vehicle infrastructure industry and the general public.

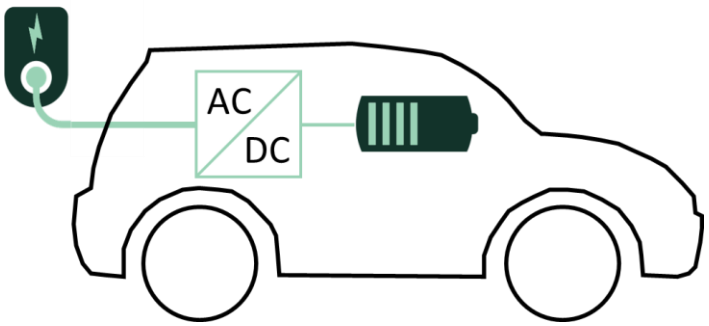
2 Introduction to Vehicle to Grid

Vehicle to grid (V2G) describes a system in which plug-in electric vehicles (EVs), such as fully electric cars and plug-in hybrids (PHEV), are connected with the power network/grid to provide energy services by either returning electricity to the network/grid or through managed EV charging functions (full rate charging, except when reduced charge rate is required to manage load across a network).

The primary difference between the "smart" chargers deployed in the Electric Nation customer trial, which are being used to provide managed EV charging services to support the local electricity distribution network by throttling EV charging rate, and V2G, is that V2G systems have the ability to export power and energy from the battery in a EV to the local electricity network.

V2G is also known as bi-directional EV charging. Bi-directional charging of EVs can be achieved in two ways:

1. **On-board**. The EV must be equipped with bi-directional power equipment: an AC/DC (alternating current/direct current[1]) converter and a DC/AC converter, or a combined converter/inverter unit.



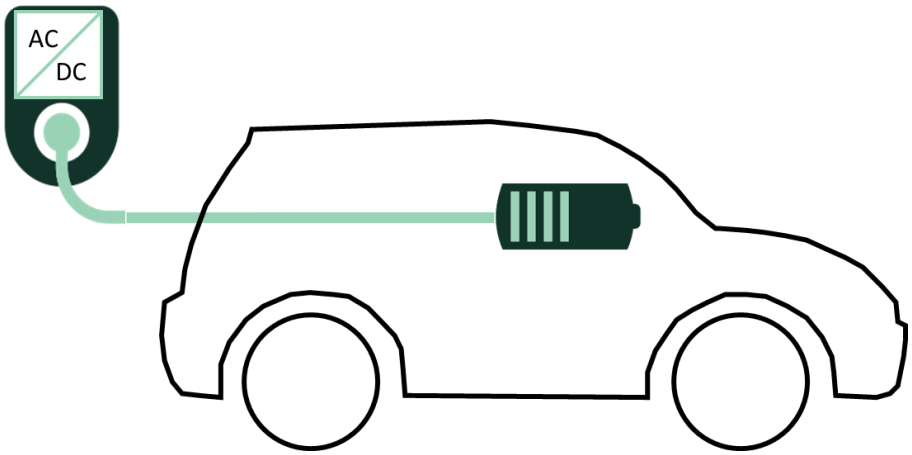
[1] Alternating current (AC) is an electric current which periodically reverses direction, in contrast to direct current (DC) which flows only in one direction. Alternating current is the form in which electric power is delivered to homes and businesses. It is the form of electrical energy that consumers use when they plug kitchen appliances, televisions and electric lamps into a wall socket. A common source of DC power is a battery cell in a torch.

A potential advantage of on-board V2G equipment is that V2G services, in particular power/energy export, could be delivered through any AC charger connection (in theory – there is no perceived reason why simple "dumb" or "smart" chargers would not cope with reverse power flow. This would have to be tested if a vehicle OEM decides to go down the route of on-board V2G functionality).

Potential disadvantages are (i) additional cost in constructing the vehicle by adding in this additional functionality, assuming bi-directional inverters are more complex electronically; (ii) the bi-directional inverters would also have to be type tested to ensure they comply with the requirements for connecting generation plant to distribution networks, which vary across global markets, adding costs; and (iii) the need for additional space to house bulkier equipment.

There are no mainstream EVs or PHEVs equipped with bi-directional inverters marketed for V2G operation at present. This does not mean that on-board power conversion equipment couldn't be adapted to provide V2G services, but there are other reasons why this is not a widespread practice, such as user and vehicle OEM concerns about potential battery degradation owing to V2G operation, though others, such as the University of Warwick, claim it can enhance battery life (Kotub Uddin, 2017)[2] and, as yet, unproven and unclear business case for V2G capability

2. **Charger-based.** Where the bi-directional power conversion equipment is installed in a charger; these chargers have to be connected directly to the EV's battery DC system, as opposed to AC connections used for slow (3.6kW) and rapid (7-22kW) charging, where EV on-board converters convert the AC power supply to DC to charge the vehicle battery.



[2] "On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system", Kotub Uddin, Tim Jackson, Widanalage D Widanage, Gael Chouchelamane, Paul A Jennings, James Marco, Energy, 2017

There are currently two DC charging standards used by EV OEMs world-wide that are relevant to the UK and European market:

- CCS (Combined Charging System) – this standard is favoured by North American and European EV OEMs and markets (manufacturers include…)

  The CCS standard currently only encompasses rapid DC charging and does not include V2G operations.

- CHAdeMO (CHArge de MOve) – this standard is favoured by Japanese OEMs (e.g. Nissan) and is also widely used across the European market for rapid chargers.

  The CHAdeMO standard does encompass V2G operation and, so, is the current standard connection option for V2G chargers/vehicles.

The technical differences between these standards are irrelevant at this point as CHAdeMO is the de-facto connection standard for V2G chargers at present. Readers interested in learning more about the standards and their differences are referred to the following sources:

- www.charinev.org
- www.chademo.com

This being said, an increasing number of European and US EV OEMs are moving towards supporting CCS (and in its "combo", combined, type 1 and Type 2 AC connector arrangements), Tesla being the latest to announce that they will provide CCS charging connectors on their vehicles. There is much speculation that CHAdeMo's days are numbered, in which case, for V2G to mature as a technology CCS needs to be adapted for V2G operations.

3 The V2G concept

The Electric Nation project is exploring the option of including V2G operations in its customer trial owing to the potential benefits of switching EVs plugged into V2G chargers to export/generation mode during managed EV charging events, when "normal" EV chargers might be set to reduced charge rate or charging paused for some EVs. There are two potential benefits; firstly, the V2G exported energy could be used to keep more EVs charging and at higher rates during a managed EV charging event (i.e. at periods of high overall electricity demand), within the local network capacity and; secondly, V2F export power could be used to support voltage on networks with high demand. Even if there is insufficient charge in an EV's battery to provide export power/energy, V2G chargers can still provide managed EV charging services, just like other "smart" chargers – reducing charge rate or pausing charging during managed EV charging events.

The concept of V2G is simple: while attached to a V2G enabled charger an EV's battery can either be charged, storing energy in the vehicle battery for use in journeys or to provide V2G services at a later point in time, or discharged, providing power and energy to the point of connection and onward into the electricity distribution network and ultimately the electricity grid.

V2G services to the electricity network/grid and wider energy value chain could include:

- Arbitrage – storing cheap electricity in the EV battery and discharging it at a point when electricity prices are high, selling this energy at a higher price than it was bought. The price differential obviously needs to cover the round-trip efficiency of storing-discharging the energy to make this worthwhile economically to the EV owner and parties involved in both the V2G infrastructure and wider energy supply value chain.
- Demand Response – either reducing or increasing the EV charging rate (power) to meet the requirements of distribution network or transmission system operators. This function can also be performed by "smart" chargers through managed EV charging.
- Frequency response – either charging or discharging the EV battery to increase power consumed by the EV or provide power to the network/grid. Response rates required vary from minutes to seconds and services can require rapid changing from charging to discharging of batteries to provide the service.
- Load balancing (a form of demand response) – in particular on local distribution networks. For example, discharging an EV to provide energy to another EV in the locality.
    - Additionally, phase load balancing could be provided by V2G chargers – if the phase of the charger and other loads on a local distribution network were known.
- Voltage support – a particular service to support the low voltage (i.e. 230V in the UK) distribution network to which a V2G charger is connected. By switching to export mode the EV battery provides power to prevent voltage dipping below statutory limits on highly loaded distribution feeders (simply, the V2G charger produces power at

higher volts than the local distribution network it is connected to, to allow energy to flow from the vehicle battery into the local power network).

For the Electric Nation project and Western Power Distribution's purposes, only local distribution network services that could be provided by V2G chargers are of interest, that is demand response, load balancing and voltage support. Phase balancing may be of use to Distribution Network Operators in the future, if and when "smart" meters are universal *and* can be used to provide data of use to distribution network operators or other systems that are put in place to measure phase loads on distribution networks.

4 Electric Nation V2G Requirement

The scope of the Electric Nation project is understanding and mitigating the impact of *domestic* EV charging, that is EV charging at EV drivers' homes. Workplace and public charging will provide similar but distinctly different challenges to distribution network operators. The owners/operators of workplace and public charging infrastructure and are not covered by Electric Nation.

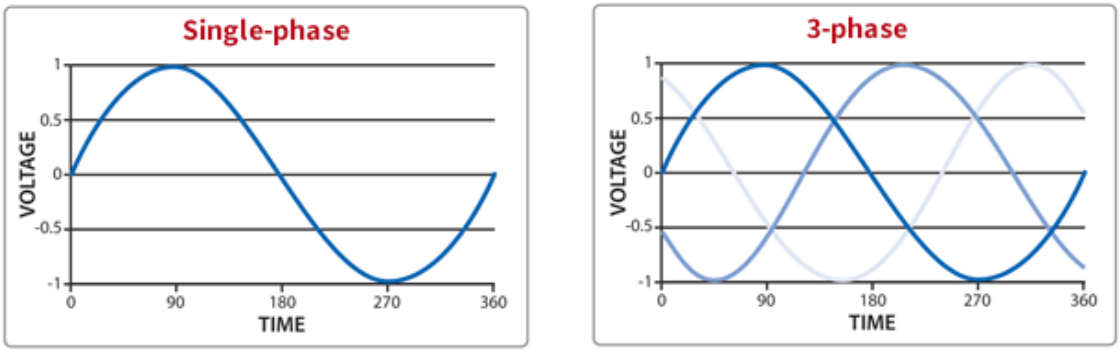
This focus on domestic EV charging means that, to understand the impacts and potential benefits to both Distribution Network Operators and customers of home-based V2G chargers, the project needs to procure a single phase[3] V2G charger, suitable for the GB domestic environment.

The requirement for a single phase V2G charger has been the most challenging aspect of this part of the project.

Other requirements include:

- "Suitable for the home environment" means that any V2G charger installed in a customer's home must be CE marked – meaning that the device/appliance complies with relevant EU safety, health and environment requirements, European or Harmonised Standards and so on and is declared to comply by the manufacturer
- Capable of charging EVs at a maximum of 32 A @ 230 V (~7 kW), preferably at this rate, but a minimum of 16 A @ 240 V (~3.5 kW) and exporting power at a minimum of 16 A and maximum of 32A, both at 230 V.

[3] Single phase electricity connections are the default for most homes in the UK, exceptions being for large and multiple dwelling homes.



Three phase electricity is more commonly used in commercial and industrial connections.
A good way of explaining the difference between single phase and three phase electricity is to imagine a paddler in a canoe. They can only move forward while their paddle moves through the water. When they lift the paddle out of the water to prepare for the next stroke, the power supplied to the canoe is zero.

Picture the same canoe with three paddlers. If their strokes are synchronized so each is separated by 1/3 of a stroke cycle, the canoe receives constant and consistent propulsion across the water. More power is supplied, and the canoe moves across the water more smoothly and efficiently.

- Compliance with either G83, for electricity generation from the unit less than 16A (3 kW or G59 for electricity generation greater than 16 A – as required by the GB Distribution Code.
- That the V2G charger can be monitored and controlled remotely through hardwire (Ethernet via home broadband internet) and/or mobile data communications
- As previously discussed, be fitted with CHAdeMO connection equipment for connection to EVs

A full specification can be found in the project's Request for Information, appended to this report.

5 The Search for a Suitable V2G Vendor

During development of the Electric Nation project it was known that V2G technology was at a very early stage of development, at an experimental and development level, not even at a pre-production prototype product development stage.

Nevertheless, inclusion of a limited testing and deployment of V2G into the customer trial element of the project was considered worthwhile, owing to the potential benefits of generation action of V2G chargers installed on overloaded LV distribution networks (reducing local demand and voltage support). The project plan therefore included a work package to undertake market research in order to search for a suitable V2G charger manufacturer, which could in turn stimulate the market to produce such a unit.

This section reports on the findings and results of this search.

Basis for the search

At the inception of Electric Nation it was known that a number of projects utilising V2G technology had been completed or were underway, these included:

- Cenex, the Centre of Excellence for Low Carbon and Fuel Cell technologies. Cenex operates as an independent not-for-profit consultancy specialising in the delivery of projects, supporting innovation and market development, focused on low carbon vehicles and associated energy infrastructure. Relevant projects include:

  - ITHECA – Intelligent Transport, Heating and Control Agent is an Innovate UK funded demonstration project that showcases the collaboration of transport, frequency response services, energy storage and district heat solutions to establish the potential of vehicle-to-grid (V2G) to maximise a combined heat and power (CHP) plant.

    This collaborative research and development demonstrator is based around the European Bioenergy Research Institute (EBRI) at Aston University, where the UK's first V2G unit has been installed. Cenex is working with Aston University to maximise outputs from the CHP unit through V2G management and intelligent control of vehicles. Outputs seek to establish the business case for the operation of these technologies as a collaborative energy solution.

    The 3 phase V2G charger used in this project was sourced from the now defunct E8 Energy, the European distributor for a, equally defunct, Japanese manufacturer, IKS.

  - EFES – Ebbs and Flows of Energy Systems is a three-year research and development project that explores the technical, social, interoperability and market barriers of vehicle-to-grid (V2G) in the UK. Through the project, three key pieces of technology have been developed:

- Virtual Power Plant (VPP) – a cloud based 'power plant', capable of utilising electricity storage assets such as static batteries or electric vehicles through a software package, controlled by electricity providers.

- V2G Unit – EVs will plug into this unit to provide both charging for the vehicle and enable it to act as a battery storage, either to provide electricity directly to a building or to the National Grid using the VPP.

- V2G Gateway – provides the control functionality for the V2G unit, enabling the unit to communicate with both a building and the VPP to determine the most appropriate charging or discharging option.

  This project commissioned the design and build of a single phase V2G charger for installation in a UK home. The contractor used was Potenza Technology Ltd, a UK company with a pedigree in vehicle electronics and electric vehicle power systems.

- A variety of Nissan inspired projects across Europe, starting in 2015 with the formation of a collaboration with Endesa, an Enel company, to develop and trial V2G solutions in Europe. Endesa/Enel providing V2G technology and Nissan V2G enabled EVs in the form of the Leaf and ENV2000 van. Recently, this partnership has been joined by Nuvve, an American software specialist providing a back office solution to the partnership, to aggregate the vehicle/fleet/charger interface to provide network and grid services. Apart from the pilot projects in Spain, Italy and France, two projects are noteworthy:

  - Denmark - Project Parker builds on two previous projects, the EDISON and Nikola projects, which have already laid the foundation for understanding the electric vehicle's potential in balancing the Danish power system. Parker represents the next technology readiness level by allowing balancing services to be applied to a fleet of electric vehicles.

    Research and development in the project is carried out as a multidisciplinary collaboration between commercial OEMs, technology providers, fleet owner and customers as well as academic institutions.

    Furthermore, Parker will interface with, and be supported by the world's first commercial pilot of series produced V2G cars providing system services, the Frederiksberg Pilot. Such collaborations will contribute to the likelihood of market adoption and ensure that the results will be applicable and re-usable to the power system in Denmark and elsewhere.

  - UK – having undertaken a proving project at Nissan's UK Technical Centre, the Nissan/Enel/Nuvve partnership is now rolling out 100 V2G chargers in a UK trial. V2G chargers will be installed at locations agreed by private and fleet owners of the Nissan LEAF and e-NV200 electric van. By giving Nissan electric vehicle owners the ability to plug their vehicles into the V2G system, owners will have the flexibility

and power to sell stored energy from their vehicle battery back to the National Grid.

In all these cases it was found that three phase V2G chargers were used or are being planned to be used.

Otherwise, searching internationally, Japan became notable as a potential source for single phase V2G chargers.

Firstly, owing to the development of Vehicle-to-Home (V2H) technology within the Japanese electricity supply industry following the 2011 Tōhoku earthquake and tsunami. Following this natural disaster and subsequent emergency at the Fukushima Daiichi Nuclear Power Plant, the majority of Japan's nuclear power plants were shut down or severely constrained for a number of years. This led to a national electricity generation crisis, with rolling black-outs across the whole country. A number of electronics companies developed V2H technology to alleviate the impact of blackouts for owners of EVs, as an alternative to home generators. These systems allow a home to be powered during a black-out by isolating the home from the distribution network and supplying the home with power from an EV's battery. Many installations also incorporate photovoltaic generations systems and static batteries.

It is not a large leap to consider taking V2H technology and converting this to, relatively simpler, V2G operation in the UK. Nichicon Corporation were identified as a leader in this technology, with some 7,000 V2H installations across Japan.

Secondly, the Jumpsmart Maui project in Hawaii incorporated a variety of public EV chargers, AC-fast and DC-rapid, into the Maui electricity network along with V2H technology, incorporating solar generation, in a number of homes. Technology for this project was supplied by Hitachi, Japan.

In both cases, single phase V2G chargers were used. However, line voltages in both countries are 110 V and frequency 60 Hz (and also 50 Hz in some parts of Japan), meaning that the technology is not readily transposable to the UK.

Search Activities

Starting with the project initiation, Western Power Distribution and its Electric Nation collaboration partners EA Technology and DriveElectric undertook a campaign of promoting the search for suppliers of single phase V2G chargers by:

- Attending and speaking at relevant industry events – inviting interested parties to contact the project and making contacts at these events
- Undertaking internet searches for potential suppliers
- Contacting known potential suppliers (e.g. Endesa/Enel, Nichicon, Hitachi, Potenza) and delivery partners in known existing/past V2G projects (e.g. Nissan, Nuvve, Cenex)

- Holding meetings to discuss their potential to supply the project or to discover pathways to suppliers.

Much of this activity resulted in one of three answers:

- Firstly, the technology is "not commercially available"
- Secondly "we can supply three phase V2G units", but the technology is "not commercially available"
- Thirdly, "we may be able to supply a single phase V2G unit", but "it's not ready yet", but will be "soon", so effectively "not commercially available"

Despite repeated discussions and chasing for some form of resolution and commitment to supply a single phase V2G unit, none was secured.

Request for Information

In order to maximise chance of success in finding a suitable V2G supplier, in May 2017 the project took the more formal step of issuing a non-binding Request for Information. This stated the project's technical requirements for a single phase V2G charger and the project's intentions in terms of timelines and proposed numbers of units required.

A copy of the ROI is appended to this report.

The ROI was issued to a number of companies who had expressed an interest in meeting Electric Nation's supply requirements:

Hitachi Europe	Selected because of its Maui project and stated interest in supplying the project.
Nichicon	Selected because of its experience in V2H supply in Japan.
Power Research Electronics B.V.	Designers and manufacturers of power solutions, claiming supply of power electronics to 70% of European rapid charger manufacturing market. Selected as it had recently announced development of a single phase bi-directional power module suitable for V2G chargers.
Last Mile Solutions B.V.	Last Mile Solutions is a specialist in the field of charging infrastructure for electric vehicles. It supplies controllers for charging stations and a back-office system including billing, roaming with other providers, etc. offering solutions for manufacturers of EV charging stations. Selected at the

	suggestion of PRE, as its preferred product solution manufacturer.
Potenza	Selected because of its previous experience in developing a V2G charger for the Cenex EFES project.
Nuvve	Selected because of its stated aim to have a single phase V2G charger in the European market by the end of 2017.
Siemens Traffic Solutions (UK)	Regarding its UK sole distributor relationship with Efacec, who is understood to be developing a single phase V2G charger.

ROI Responses

No response / no progress:

PRE stated that it preferred supplying the power electronics only and, as stated referred Electric Nation on the Last Mile Solutions.

Last Mile Solutions stated an interest, but wanted to partner with a UK manufacturer. It was referred on to Potenza. Electric Nation also undertook some market research to find other suitable UK manufacturers, only to find that no UK charger manufacturer had, at that time, DC EV charger product experience.

Potenza expressed a great deal of interest in supplying the project and could possibly have worked with Last Mile Solutions and PRE. Potenza had already stated that their prototype supplied to the Cenex EFES project would need significant re-design as their original power electronics system was no longer available. The possible link up with PRE and Last Mile Solutions could have been a solution. However, Potenza sought product design and development funding, which it was decided was outside of the scope of the Electric Nation project and Network Innovation Allowance funding.

Nuvve did not respond to the ROI.

Siemens declined to respond after discussions with Efacec.

Positive Response to the ROI:

Positive responses were received from Nichicon and Hitachi Europe. These responses have led to further discussions and progress as outlined below.

Western Power Distribution has requested that both potential suppliers be pursued with the objective of getting at least one and possibly both suppliers' products installed on the Electric Nation charger test system at EA Technology, Capenhurst. The objective being to test one or both V2G chargers before deploying a small number of V2G chargers into the customer trial

in 2018. This mitigates the risk of one of the potential suppliers failing to meet the project's objective. If both are installed on the tests system then the best performing unit will be selected for the customer trial deployment, depending on availability of production units for deployment into the customer trial.

Nichicon – progress to date

Following the ROI process, Nichicon and CrowdCharge, the latter being one of the suppliers of managed EV charging services to Electric Nation, formed a partnership to deliver V2G chargers to the project (in fact CrowdCharge is now Nichicon's agent for V2G chargers in the UK).

Nichicon has committed to supply a pre-production prototype single phase V2G charger to the Electric Nation test system by January 2018 (target being the end of 2017, dependent on shipping time). Electric Nation has been assured that this unit is being manufactured at time of writing.

This pre-production prototype will not be CE marked or G59 certified. As this unit will only be installed in an industrial setting CE marking is not essential. The G59 issue is being addressed by installing an independent G59 relay on the power supply to the V2G charger on the Capenhurst test system.

Production units, planned for delivery in spring / early summer 2018, supplied for the customer trial will be CE marked and G59 certified.

Further, the pre-production unit will be an adapted Japanese model, to overcome the supply voltage difference a step up/down transformer (110 V/240 V) will be supplied in a "2-box" package (charger and supply/connection electronics).

The production units will be single piece 230V rated units. N.B. the supply frequency difference between some parts of Japan (60 Hz) and the UK (50 Hz) can be managed by programmable power electronics.

A draft specification document for the Nichicon production units has been received from Nichicon and reviewed by EA Technology. A second draft is being produced by Nichicon following requests for clarification and removal of vehicle to home functionality that is not required by the project or could present conflicts with the Distribution Code if enabled (in particular the capability to island a home in the event of a black-out). Unfortunately, at time of writing, owing to confidentiality agreements this specification cannot be published in this report.

To be able to control the Nichicon V2G charger alongside the other "smart" chargers in the Electric Nation customer trial, CrowdCharge needs to adapt its systems; the unit is controlled through a Japanese "smart home" communication protocol – Echonet-Lite.

- CrowdCharge has developed a special controller unit that will convert OCPP commands to Echonet-Lite commands

- CrowdCharge also needs to adapt the OCPP command set to provide the necessary generation commands, utilising "redundant" OCPP commands to do this where necessary. To date CrowdCharge has built a library of Echonet-Lite commands and is awaiting confirmation of the exact commands required for V2G charger control from Nichicon.
- To test the special controller and OCPP/Echonet-Lite command conversion, CrowdCharge also needs a sample Nichicon controller board from the charger, which has been requested from Nichicon in advance of delivery of the charger.

Hitachi – progress to date

As already stated, a second supplier of V2G chargers is being pursued to mitigate the risk of failure to supply or functional failure of the Nichicon charger.

Hitachi has made verbal commitment to deliver a sample three phase V2G charger for testing as a pre-production prototype, with production single phase units (with G59 certification and CE marking) becoming available mid-2018.

As with the Nichicon unit, adaptions need to be made to enable control of the charger, as Hitachi does not have a functional back office system to control its chargers at this time. GreenFlux has been commissioned to scope out developing a command system to interface with Hitachi's mobile-phone V2G charger system. This mobile phone system allows users to set charge rate/generation rate. This GreenFlux "back office" will be a separate system from its managed EV charging system, but will be able to control the V2G chargers in tandem with "smart" chargers under their control.

The aim of the scoping work is to gauge the time and cost of GreenFlux developing this bespoke back office module. On receipt a decision will be made as to whether to pursue this option depending on how the development timescale fits with the overall project plan and budget.

In the meantime, the adaptations to the Capenhurst test system will encompass installing the Hitachi V2G charger, as the pre-production prototype is also unlikely to be G59 compliant.

6 Recommendations

Given the current state of development of single phase V2G chargers, i.e. that there appears to be a limited choice in suppliers and that both suppliers can only commit to providing pre-production prototypes for testing, the Electric Nation project team have concluded that the project should pursue both options for testing. This will mitigate the risk of delay in delivery or performance failure of one or the other V2G units.

On completion of testing a decision will be made whether to deploy a limited number of V2G chargers (say, 5-6, depending on costs) into the customer trial and which V2G charger to deploy, based on technical performance of the V2G charger itself and the controlling back-office during testing.

To this end, the next steps are:

1. Nichicon to provide CrowdCharge with required Echonet-Lite command set to control V2G charger and sample charger controller board for development purposes – ongoing.

2. CrowdCharge to develop OCPP/Echonet-Lite command interface programme for their specially adapted controller - ongoing.

3. CrowdCharge to test interface with V2G charger control board – December 2017

4. EA Technology to install hard standing, power supply (including G59 relay) and communications cables in advance of V2G charger delivery (or deliveries if Hitachi unit purchase goes ahead) – ongoing.

5. GreenFlux and Hitachi to scope out works required to build back office on GreenFlux platform to control Hitachi V2G charger – ongoing.

6. Option to commission GreenFlux to build the back office for Hitachi interface - by mid-November.

7. Install Nichicon V2G charger - January 2018.

8. Option to install and commission Hitachi V2G charger – February 2018.

9. Test Nichicon V2G Charger January- March 2018.

10. Test Hitachi V2G charger February – April 2018.

11. Decision to purchase and deploy V2G chargers into customer trial March /April 2018 with a view to install five or six into customer homes by July/August 2018 for a six-month test campaign.

Appendix 1 – Request for Information issued to candidate suppliers

REQUEST FOR INFORMATION

SUPPLY OF V2G CHARGERS FOR CUSTOMER TRIAL

Introduction

This Request for Information is published by EA Technology, in its capacity as an Electric Nation project collaboration partner with Western Power Distribution.

All responses to this RFI will be treated in strict confidence by EA Technology at the request of respondents to this call.

The Electric Nation Project

Electric Nation is the customer-facing brand of CarConnect, a Western Power Distribution (WPD) and Network Innovation Allowance funded project. WPD's collaboration partners in the project are EA Technology (the author of this report), DriveElectric, Lucy Electric GridKey and TRL.

Electric Nation, the world's largest electric vehicle (EV) trial, is revolutionising domestic plug-in vehicle charging. By engaging 500-700 plug-in vehicle (PIV) drivers in trials, the project is answering the challenge that when local electricity networks have 40% - 70% of households with EVs, at least 32% of these networks across Britain will require intervention posed by the My Electric Avenue trial[1].

The project is developing and delivering a number of smart charge solutions to support plug-in vehicle uptake on local electricity networks. The primary outcome of the Project will be a functional specification for PIV demand management services that GB Distribution Network Operators (including WPD) can use to procure such services as

[1] http://myelectricavenue.info/

COLLABORATION PARTNERS

Electric Nation is the customer-facing brand of CarConnect, a Western Power Distribution (WPD) and Network Innovation Allowance funded project. WPD's collaboration partners in the project are EA Technology, DriveElectric, Lucy Electric Gridkey and TRL.

ea technology · driveelectric · Lucy Electric · TRL · WESTERN POWER DISTRIBUTION *Serving the Midlands, South West and Wales*

PIV demand grows to the point where distribution networks become stressed by PIV demand. A second key outcome will be a tool that analyses plug-in vehicle related stress issues on networks and identifies the best economic solution. This 'sliding scale' of interventions will range from doing nothing, to smart PIV demand management, possibly including taking energy from vehicles and putting it back into the grid (vehicle to grid, V2G, technology), through to traditional reinforcement of the local electricity network where there is no viable smart solution.

The development of the project deliverables is being informed by a large-scale trial involving PIV drivers that will:

- Expand current understanding of the demand impact of charging at home on electricity distribution networks of a diverse range of plug-in electric vehicles - with charge rates of up to 7kW+, and a range of battery sizes from 20kWh to 80kWh+.
- Build a better understanding of how vehicle usage affects charging behaviour.
- Evaluate the reliability and acceptability to EV owners of smart charging systems and the influence these have on charging behaviour. This will help to answer such questions as:
    - Would charging restrictions (PIV demand management) be acceptable to customers?
    - Can customer preference be incorporated into the system?
    - Is some form of incentive required?
    - Is such a system 'fair'?
    - Can such a system work?

The results of this project will be of interest and will be communicated to the GB energy/utility community, to UK government, to the automotive and PIV infrastructure industry and to the general public.

V2G in the Electric Nation Project

As mentioned above, V2G is a potential solution to supporting electricity distribution networks at times of high domestic electricity demand – exporting power and energy from electric vehicle batteries to support other demands on local low voltage distribution networks (including other electric vehicles charging) and, so, supporting network voltage.

Electric Nation wishes to deploy a number of V2G chargers into its customer trial for the second year of the trial (January-December 2018) – the number being dependent on the cost of units.

Before deploying into the customer trial the project wishes to test a V2G unit at EA Technology, Chester, UK on a smart charger test system built specifically for the project – this test system has twelve smart chargers, where multi-EV charging tests can be undertaken to test smart charging (and V2G) control systems. V2G charger tests would have to commence October 2017 at the latest to ensure deployment of V2G chargers into the trial in early 2018.

Request for Information

The remainder of this document sets out Electric Nation's requirements for V2G chargers.

Technical Requirements

V2G charger supplied must be

Requirement	Test Unit	Trial units	Note
CE Marked	Optional	Y	
Compliant with CHAdeMo standard	Y	Y	
Single phase connection Operating voltage: 230V AC Nominal	Y	Y	1
Input Power Max: 7kW (32A @ 230V AC)	Y	Y	2
Capable of "smart Charging"	Y	Y	3
Capable of exporting energy from the connected vehicle through the AC supply connection: • For export power < 3.68kW (16A @230V AC), compliant with ENA Engineering Recommendation G83/2 OR • For export Power 3.68kW - 7kW (32A @230V AC), compliant with ENA Engineering Recommendation G59/2	Y	Y	4 5,6
Capable of both Ethernet and/or GPRS/GSM communication	Y	Y	
Controllable by a third party	Y	Y	7
Installation must conform to the IET's Code of Practice on Electric Vehicle Charging Equipment Installation	Optional	Y	8

Notes

1. Spur (parallel) connection to household electricity supply required
2. This is maximum power consumed by the charger – output to connected vehicles will be necessarily lower owing to any power losses in the charger itself
3. i.e. charger output power to connected plug in vehicle can be managed from maximum allowed (set by input power consumption) to any power rating including zero (paused charging).
4. See http://www.dcode.org.uk/assets/images/ENA_ER_G83_Issue_2_(2012).pdf
5. See http://www.dcode.org.uk/assets/images/ENA_EREC_G59_Issue_3_Amendment_2_(2015).pdf
6. Electric Nation is considering limiting export power to 7kW, units capable of higher power outputs will be considered, but must be capable of being limited to 7kW
7. Options include, direct control by third party via OCPP 1.6 (where additional commands can be supplied for V2G operation) and indirect control, where third party sends commands to V2G vendor's back-office (via API) that then enacts smart charge/V2G commands to V2G chargers.
8. See http://www.theiet.org/resources/standards/ev-cop.cfm

Timescales for Supply

As already indicated:

- Supply and installation of tests unit at EA Technology site, Chester, UK, must take place on or before 1st October 2017.
- Assuming successful conclusion of tests of communications, charger management system(s), V2G charger performance supply of a number of V2G chargers in January/February 2018 to be installed in trial volunteer homes in the same period.

In addition, the project needs to make a decision whether to go ahead with incorporating V2G into the trial, dependent on responses to this RFI, mid-August 2017 at latest.

To Respond to this RFI

This is a request for information only and will not be treated as a binding offer of contract.

All information supplied will be treated by EA Technology in strict confidence at your request. Otherwise information supplied may be shared with the following project partners for evaluation purposes:

All information provided
- Western Power Distribution
- Drive Electric Limited

Communications and control related information only
- CrowdCharge Limited
- GreenFlux B.V.

Please supply:

1. Technical information regarding the V2G charger you wish to offer the project, addressing the requirements listed above as a minimum.
    - Please highlight any variations from our stated requirements and justify them
2. Your thoughts on the delivery timescales stated above – can you meet or beat Electric Nation's timescales?
3. Realistic, indicative price for supply of these V2G chargers (F.O.B. EU/UK), this price will not be treated as an offer of contract and will be used for evaluation purposes only. For information – the number of units purchased will be determined by price, at a minimum suppliers can expect an order for 1 test unit + 10 trial units.

Please address any questions and send responses to this RFI to Nick Storer, nick.storer@eatechnology.com, by 5PM Tuesday 6th June 2017.

What Happens Next?

EA Technology and the named collaboration partners and suppliers named above will evaluate the responses.

We may request clarification and further information.

EA Technology on behalf of the Electric Nation project may then either issue a formal request for quotation or enter negotiations with one or more respondent to this RFI or any other party for the supply of V2G chargers to the project.

Please note that the Electric Nation project may decide not to proceed with V2G charger procurement.