UK and International Charging Options

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Executive summary

It is anticipated that the rapid uptake of Plug-in Vehicles (PIVs) will lead to excessive strain on the electricity network if PIV charging coincides with peak electrical demand. This was proven in the recent My Electric Avenue project, to which Smart EV is a direct successor. To avoid costly network reinforcement it is proposed that PIV charging is managed to avoid peak periods. A technical review paper of publicly available information on UK and international PIV charging technologies, trials and communication methods is presented. This is to support the Smart EV Project in developing an ENA Engineering Recommendation (or equivalent) to allow the range of future chargers to interact with a common device for the purpose of load management.

The review presents an investigation of PIV charging trials with priority given to those exhibiting smart charging studies. A summary of trials is presented and themes are drawn; a set of options detailing potential smart charging solutions is given as a representation of current technology and indication of future solutions. Existing smart charging solutions are also presented, providing details of functions and communication methods employed by the systems. Communication protocols capable of providing controlled charging solutions are explained, specifically Open Charge Point Protocol (OCPP) and Open Smart Charge Protocol (OSCP). Consideration is also given to the uptake of vehicle to grid (V2G) technologies which could radically alter smart charging requirements. Information regarding commercial V2G products, communication Standards and ongoing trials is presented.

Conclusions

C1. A review of trials which considered the impact of PIV uptake has shown that controlled charging solutions can offer a viable and cost effective means of avoiding significant cost to electricity customers due to uptake of PIVs.

C2. Trials have shown the capability for controlled charging using on-vehicle, on-charger and intermediate devices to shift load from PIV charging.

C3. Trial results suggest that smart charging solutions may have greater application for alleviating network load at peak times in a domestic setting, where most vehicles are charging at these times.

C4. ToU tariffs were found to effectively mitigate against peak load stress on electricity infrastructure but DNO roll-out in GB may be prohibited by cost without roll-out of residential ToU tariffs, including targeted DuoS charges.

C5. A range of DSR solutions are available with the capability to limit PIV charging, predominantly located within charge points and provided as an optional item.

C6. Communication and control protocols used by the available DSR solutions are often proprietary. Open protocols (OCPP and OSCP) provide the required functionality for the solutions developed by OEMs and provide system agnostic communications. OSCP/OCPP messages can be communicated using any internet IP based mechanism, trials no particular connection method is favoured or appears best suited from trials and existing systems.

C7. Controlled charging is facilitated by the IEC 61851 Standard for communication between charge point and PIV (Pilot control). This is widely adopted and allows charge points to vary available charge power to the PIV.

C8. The UK government endorsed SMETS 1.58 offers auxiliary load control switches which have capability to switch PIV charging equipment, this has not been widely used to date.

C9. V2G systems are at the later-stage of trials, but existing Standards and protocols do not include provision for the systems. A standalone V2G Standard is available.

C10. The PIV industry has developed and trialled systems capable of delivering controlled charging solutions. However, there is no accepted standardised approach for controlled charging such that a DNO could procure such a service. There is clear need to produce a controlled charging Standard providing system interoperability, allowing wide scale adoption and acceptance by industry and customers.

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Appendices

Abbreviations

AC	Alternating Current
ADMD	After Diversity Maximum Demand
ALCS	Auxiliary Load Control Switch
ANM	Active Network Management
CNO	Charge Network Operator
CNP	Charge Network Provider
CP	Charge Point
CSO	Charge Service Operator
CSP	Charge Service Provider
DC	Direct Current
DNO	Distribution Network Operator
DNP3	Distribution Network Protocol
DSR	Demand Side Response
DuoS	Distribution use of System (Charges)
ENA	Energy Networks Association
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GPRS	General Packet Radio Service
GSM	Group System for Mobile Communications
HAN	Home Area Network
IP	Internet Protocol
LC	Local Controller
LCL	Low Carbon London
MEA	My Electric Avenue
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturing
OSCP	Open Smart Charge Protocol
PIV	Plug-in vehicle
PLC	Powerline Communication
SMETS	Smart Metering Equipment Technical Specification
TCP	Transmission Control Protocol
ToU	Time of Use
V2G	Vehicle to Grid

1. The Smart EV Project

1.1 Background

This technical review paper is presented as a deliverable for the Smart EV project (NIA Project Reference NIA_SSEPD_0026 "Management of plug-in vehicle uptake on distribution networks").

The Smart EV Project is providing a viable solution to the challenges of plug-in vehicle (PIV) uptake in GB, following a previous innovation project by Scottish and Southern Energy Power Distribution and EA Technology: My Electric Avenue (MEA) (the public facing name of the Low Carbon Networks Fund, Tier 2 project Innovation-Squared EV[1]). MEA identified the potential to avoid £2.2billion of cost for electricity customers if demand side response was rolled out for PIV charging. However, MEA also signposted that the industry currently lacks a standardised mechanism to access this response.

This review paper presents information regarding the current state of UK and international charging technology, including communication methods, protocols, variations between existing systems and the readiness of a standardised and industry supported method for controlled charging of plug-in vehicles (PIVs).

The overall objective of this report is to set out the current technology in the market for controlled PIV charging. This will support the Smart EV Project in developing an ENA Engineering Recommendation (or equivalent) to allow the range of future charge systems to interact with Distribution Network Operator (DNO) systems for the purpose of load management.

1.2 Project Aims

The Smart EV Project will seek to address the issues outlined above. The outputs will be:

1. Provision of industry agreed material to inform an ENA Engineering Recommendation (or equivalent) available to third parties for supply and manufacture of the home end and/or substation end controllers (the Solution).

2. A functional specification describing the system components and operation to allow vendors to produce a compliant Solution.

3. Evidence of UK PIV industry acceptance of the Solution, including OEM engagement and clear path to adoption.

4. Customer Messaging Strategy to facilitate customer understanding and buy-in to PIV controlled or smart charging and network demand response tools to improve customer acceptance of the solution(s).

1.3 Report Structure

Following a description of the scope and objectives (Section 2), this report sets out a technical review of:

- UK and International Trials (Section 3)
- Options for managing PIV charging, considering:
  - Existing systems (Section 4.1)
  - Applicable Standards and Regulations (Section 4.2)
  - Applicable protocols for communication between external system, PIV charge units and PIVs (Section 4.3)

[1] See: www.myelectricavenue.info

- Trials, Standards, protocols and technologies relevant to vehicle-to-grid (V2G) systems, which are relatively untested in the UK but will have material impact on the Smart EV project (Section 5).

2. Scope and Objectives

This report presents a technical study to deliver an informed view of the problems and existing solutions associated with PIV smart charging. The objectives are:

- Information gathering on UK and international trials
- Technical review of systems, Standards and Protocols

The scope of this report is to deliver:

- Desk-based research based on information in the public domain, informed by EA Technology's existing expertise in this space.
- Review of technologies relevant to residential or light industrial customers, specifically:
  - Light vehicles (cars and vans)
  - Charging technologies suitable for installation without application to a DNO for new connection. Therefore, rapid chargers are outside the scope of this work but AC charge units up to 22 kW (i.e. 32A, 3 phase) have been included

3. UK and International Trials

3.1 Reasons for Inclusion

This section sets out desk-based research into existing UK and international trials in the PIV space, with a view to understanding the industry leading PIV charging and smart charging solutions. In order to deliver the most relevant review, the trials reported have been selected based on meeting one or more of the following criteria:

- Focus on PIV smart charging solutions, prioritising those which aim to alleviate peak load on the local network.
- An interaction between PIV and network operator (whether local, regional or system level).
- Ongoing, or completed within the past three years (it is likely that any project outside of this time frame will have been superseded by the pace of change in PIV, charger, and network technologies).

The remainder of this section summarises key themes identified within the trials, relating to Time of Use tariffs, Demand Side Response (DSR) and communication methods. The section concludes with a set of options identified from the trials for PIV smart charging.

3.2 Trials Reviewed

Information in the public domain is often limited to protect the intellectual property of the solution developers. In some instances, the material released is limited in technical scope and instead provides detail of the project work, often in the form of a press release. This has limited the number of trials that it has been possible to review appropriately. For those presented below, it has been possible to provide an informed review of the approach, methods and results collected.

Table 1 summarises the reviewed trials, further information on each trial is given in Appendix I.

Table 1 UK and International PIV Trials

No.	Project Title	Date	Location	Description
1	Electric Vehicle Intelligent Infra Structure (ELVIIS)	2011-2013	Sweden	A small trial based on installing smart charge control within a PIV as opposed to a Charge Station. The PIVs communicate using the mobile network to receive charging schedules based on energy prices and grid capacity.
2	Preparing the Strategic Road Network for EVs	2013-2015	UK	A feasibility study to investigate if the UK strategic road network could support the uptake of EVs by introducing subsurface inductive charging facilities. Not focussed on smart or controlled charging.
3	The Mobility House - EV Smart Charging Trial	2014-2015	Germany	A small domestic smart charging station trial which schedules vehicle charging based on energy cost data. The vehicle actively charges at off-peak, lower cost times.
4	Low Carbon London (LCL): Impact & opportunities for wide-scale EV deployment; *Opportunities for Smart EV Charging*	2013-2015	UK	A feasibility study; monitored the driving and charging patterns of 32 PIVs over a 24hr period. Developed an algorithm to determine if charging could be shifted to off-peak demand periods, without restricting driver use of the vehicle. Findings; shifting charging to the evening, reduced peak load without reducing available range to the driver.
5	LCL; Smart EV Trials: *Time of Use*	2013-2015	UK	A ToU meter tariff for 10 EV owners, control group of 58 EV owners. Both sets had sub-meters installed to monitor and compare the domestic charge station use. Findings; participants modify their behaviour for a better off-peak rate. Without an incentive, participants charge at their convenience.
6	LCL; Smart EV Trials: *Active Network Management (ANM)*	2013-2015	UK	An ANM system to control 62 public charge points in the London area. A substation device compared network capacity with the charging load of PIVs. If the network approached capacity a PIV load reduction was requested. Findings; ANM and intelligent chargers can provide a real time load management solution for public charge points.
7	My Electric Avenue	2012-2015	UK	Trial of a smart charge solution, to understand charging habits and customer acceptance of smart charging. 200 participants (100 Trial, 100 Control). Controlled EV charging using an 'intelligent socket' and powerline communications (PLC). Findings; smart charging can curtail demand. Customers were accepting of the technology.
8	PIV Charging Pilot Program	2013-2015	USA	DNO trial of ToU tariff. Offered a whole house tariff (24 Participants) and EV only Tariff (130 Participants). EV only tariff installed a sub-meter, a subset also installed smart-charging

No.	Project Title	Date	Location	Description
				stations to provide metering and demand response switching. Findings; DSR could manage network peak load, ToU tariff seen to shift charging to off-peak periods. Result; DNO offer whole house ToU to PIV owners.
9	The Green eMotion	2011-2015	EU	A large EU funded project focussed on developing a European framework to support the future uptake of EVs considering the social, technical and economic barriers to uptake. The project identified the need for agreed, cross-OEM compliant ICT protocols and standards for public charging infrastructure. The works acknowledged a gap in smart charging standardisation[2].
10	eMobility ICT Interoperability Innovation (eMI[3])	2015 -	EU	The eMI[3] group was founded by The Green eMotion project. It is a group of companies in the EV marketplace, developing ICT standards and protocols to allow for interoperable charging equipment and billing regardless of OEM or vendor, it is not focussed on providing a smart charging solution. It has so far developed a specification containing agreed terminology and definitions.

3.3 Key Themes

Based upon a review of the trials listed in Table 1, the following themes have been identified. The specific technologies, Standards, and protocols demonstrated by these trials are set out in Section 3.4 and evaluated in Section 4.

3.3.1 Theme 1 - Time of Use Tariffs - Passive

A common method employed to reduce load at peak demand times, is through the use of variable energy pricing. This is known as a Time of Use (ToU) tariff, which applies increased electricity prices at certain times of day, usually peak demand hours (6pm-8pm)[3]. Several trials made use of such a system to incentivise PIV owners to charge at off-peak times to reduce stress on both generation and distribution capacity. In trials five and eight, a ‘passive’ ToU trial was used. This meant customers were aware of the variable pricing but that they actively decided whether to defer charging to off-peak periods, or not. The results of these trials found that customers were responsive to the variable pricing and 70% of domestic customers in trial five, shifted charging to off-peak periods[4]. Figure 1 is an extract from the results of trial five, illustrating the difference between peak time consumption (14:00-20:00) of a control group and a passive ToU tariff group of EV owners. However, trial five also found that it is unlikely to be cost effective to implement ToU tariffs in GB as a means to mitigate PIV uptake, due to high cost of changes to DNO and supplier settlement systems. It should be noted, that in the event that ToU tariffs are implemented for domestic customers, including distribution use of system (DuoS) charges specific to certain locations, then this solution could be cost effective.

[2] Heike, Dr. Barlag, Green eMotion, WP11 Deliverable 11.8, (2015) “Final publishable summary report” pg. 20.
[3] Low Carbon London (2014) “Impact & Opportunities for wide-scale EV deployment”, pg. 55.
[4] UK Power Networks (2014) “Opportunities for smart optimisation of new heat and transport loads”, Pg. 46.

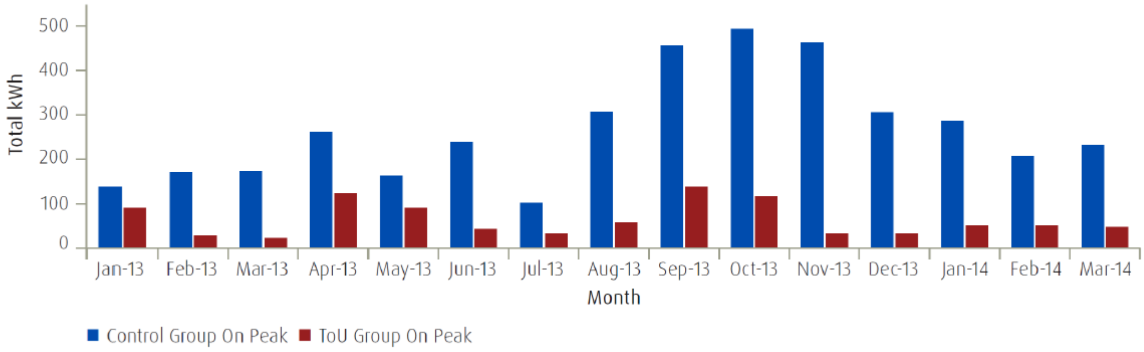

Figure 1 : Peak Hour Consumption, Control Group and ToU Group. UK Power Networks; Opportunities for smart optimisation of new heat and transport loads.

3.3.2 Theme 2 - Time of Use Tariff – Active

Trials one and three also made use of a ToU tariff to inform the smart charging process. In these cases a smart charging station actively planned charging schedules to ensure that, where possible, charging took place at the lower cost rate, alleviating load at times of peak demand. These can be described as 'active' ToU trials.

The smart charging control system, for determining the schedule of charging, can be in the PIV or a standalone intelligent Charge Station. In either case, a communication method is required to inform the charge controller of the ToU tariff and meter the usage. Communication media trialled includes using the GPRS network, and public fixed line Internet Protocol (IP) based systems (e.g. ADSL) to connect with a central system. There are no details of specific protocols or standard message sets being developed to facilitate this type of system.

As with passive Time of Use Tariffs, it is likely that the cost of implementing these systems in GB will be prohibitive without wide adoption of ToU tariffs for residential customers, including targeted DuoS tariffs.

3.3.3 Theme 3 - Demand Side Response (DSR)

The use of Demand Side Response (DSR) solutions recurs across several trials. DSR alleviates pressure on distribution networks at times of peak load, by shifting demand. This can be achieved through several methods, including voltage control and active load switching.

Trials one, six, seven and eight all utilised a form of DSR to reduce the load on the local network. The trials were conducted across both domestic and public charge points, focussing on the effects of PIVs on grid capacity and how DSR could be used to actively shift charging load. One scheme (trial 6) issued requests to vehicles to shift load, while others (trials 1 and 7) actively switched or ramped available current to charge points to control the local network demand.

A variety of communication connection methods were employed for the DSR control signals, including Power Line Carrier (PLC) communications between substations and charge points, communication over the GPRS network and public IP communications (hardwire or wireless).

The trials demonstrate that DSR smart charging methods offers significant opportunity to reduce load at peak times on the network and avoid costly network reinforcement[5]. It was also found that DSR more efficiently mitigates peak load than ToU tariffs[6]. It was noted anecdotally that DSR for

[5] EA Technology (2015) "My Electric Avenue: This is what we've learnt", p. 9.
[6] UK Power Networks (2014) "Opportunities for smart optimisation of new heat and transport loads", p. 66 Section 6.2.3.1

public charging points had less availability compared with domestic charge points, particularly at peak times[7].

3.3.4 Theme 4 - Domestic/Public Charge Stations

The reviewed trials made use of a mixture of domestic and public charge points. A theme across several trials was smart charging would be more applicable in a domestic setting. A study by the Energy Technologies Institute found that for the majority of car journeys, the destination is a domestic setting[8]. This agrees that charging solutions will be best placed at consumer homes.

Additionally, the 'availability' of PIVs for smart charging solutions is limited to the number of cars connected at the time. Public charge points are commonly used throughout day-time (working) hours before peak load occurs whereas domestic charging significantly contributes to the evening peak load[9]. Trial seven found that when DSR was employed to manage evening peak load, customers were tolerant of the curtailment due to the large window for unrestricted charging overnight.

It was also reasoned that public charge points are operated by commercial entities who have an interest in charging at all times and would be averse to the effects of controlled charging on revenue[10].

For the above reasons, it was found by the trials that smart or controlled charging would be best suited to domestic charge stations.

3.3.5 Theme 5 – Communications, Standards and Protocols

A theme throughout all of the trials was the need for secure, reliable and readily available communications, Standards and protocols Communication is required for active ToU tariff management and for DSR solutions, which were both found to provide opportunity for significant peak load shifting. The projects trialling these schemes made use of a variety of existing connectivity methods, as follows:

- PLC communications, where the existing grid is used as the communication medium for transfer of switching instructions and measurements,
- Mobile network communications using the GPRS network,
- ANM connectivity using IP, Distribution Network Protocol (DNP3), Modbus protocol and virtual private networks (VPN), and
- Direct communication with the PIV controllers through the vehicles mobile network connection.

The trend across trials indicates that although communication is required, there is no preferred method and many options are being investigated. Often the exact connectivity and communication protocol details/techniques are commercially sensitive and not publically available.

Trial nine identifies the requirement for interoperable communication protocols across public charging infrastructure to enable the wide scale acceptance of EVs[11], citing that ready access to any charge point will encourage uptake. Trial ten is focussed on producing such an interoperable ICT

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[7] UK Power Networks (2014) "Opportunities for smart optimisation of new heat and transport loads", p. 66 Section 6.2.1

[8] Liam Lidstone (2014) "Energy Provision for Low Carbon Vehicles". Available: http://www.eti.co.uk/wp-content/uploads/2014/09/Energy-Provision-for-Low-Carbon-Vehicles-UPDATED-WEB.pdf

[9] EA Technology (2015) "My Electric Avenue: This is what we've learnt; Doubling the Load; ADMD" Pg. 8.

[10] Low Carbon London (2014) "Impact & Opportunities for wide-scale EV deployment", Section 5.1.3 Pg. 60.

[11] Barlag Heike, Green eMotion, WP11 Deliverable 11.8, (2015) "Final publishable summary report" p. 4. Available: http://www.greenemotion-project.eu/upload/pdf/deliverables/D11_8-Final-publishable-summary-report-V1_4.pdf

system to allow problem free charging and billing between EV customers and any charge service provider or charge point. Although there is no indication the system will cover controlled charging the aim of the group is to support any EV initiative through harmonising and supporting interoperability. Trial nine acknowledges the need for smart or controlled charging to avoid grid reinforcement and suggests it may form the basis of future standards. Neither trial has committed to producing a controlled or smart charging standard, or suggested the form of a solution.

3.4 Options identified from Trials

The review of these trials has identified the following options for managing PIV charging, which comprise of technologies, Standards and protocols.

3.4.1 Smart Charge Control Installed within PIV

Trial one made use of smart charge control installed within the PIV. The major benefit of this technique is that it enables smart charging, without updating any existing infrastructure and can occur wherever the vehicle owner chooses to charge. Once the vehicle is capable of controlling the smart charge sequence it must also be able to receive information concerning the capacity and loading on the local network. This would rely on communications between the vehicle and a central system; trial one used the GPRS to achieve this communication. However, this has reliability limitations which are likely to discourage adoption by DNOs, if all PIVs utilise mobile networks. Additionally a protocol for the transfer of messages between all DNOs and PIV automotive OEMs would need to be developed and agreed; this is a substantial task but could be simplified through the adoption of an open protocol like those described in section 4.3.

3.4.2 Time of Use Tariffs

Several of the trials specifically investigated the effects of a ToU tariff on the network peak load. This strategy could be applied through a price incentive mechanism or alternatively through an automatic control function. In either instance the ToU approach was found to relieve network stress at peak hours. It is limited by customer adoption and acceptance of the system, and is reported to be less cost effective than alternative trialled DSR solutions for the low voltage network for GB.

3.4.3 Demand Side Response

The opportunity for a DSR solution is clear from the trials. This technique has been found to reduce load at peak times. As identified in Section 3.3.4, the application may be best suited to a domestic environment due to the coincidence of charging and peak load but it is also possible to employ the solution at public charge points. In order to develop a suitable DSR solution, communication must be reliable between all devices. Additionally, an agreed DSR solution must be adopted which is appropriate to all parties, including;

- Network operators (DNOs, National Grid)
- EVSE suppliers
- Automotive OEMs
- Customers (who must be receptive of charging curtailment/shifting)

The exact solution and method of communication between EV controller and central system may vary although an agreed, equipment agnostic set of Standards and parameters would enable effective market penetration. Specific solutions for provision of DSR for PIV charging are discussed in Section 4.1.

3.4.4 Communications & Protocols

Various communication systems have operated with some success within the trials reviewed. Trial one made use of the GSM mobile communication network to poll available local network capacity, this method has limitations as signal reliability is not guaranteed. Trial six developed an ANM communication architecture using GPRS between the charge point management system and charge point, again this method can suffer intermittent reliability issues. Trial seven made use of PLC communication, which benefits from only communicating with connected customers but has shown reliability problems for complex LV network arrangements.

The majority of the trials have not released the exact protocol employed by their solutions. It was possible to gain an insight into the protocols employed by trial six to control DSR requests within a public smart charge infrastructure, illustrated in Figure 2. The ANM controller determines the desired charging solution and communicates with the charging network using a secure internet connection. The charging network then communicates a command to the charge station to regulate the current flow to a connected vehicle.

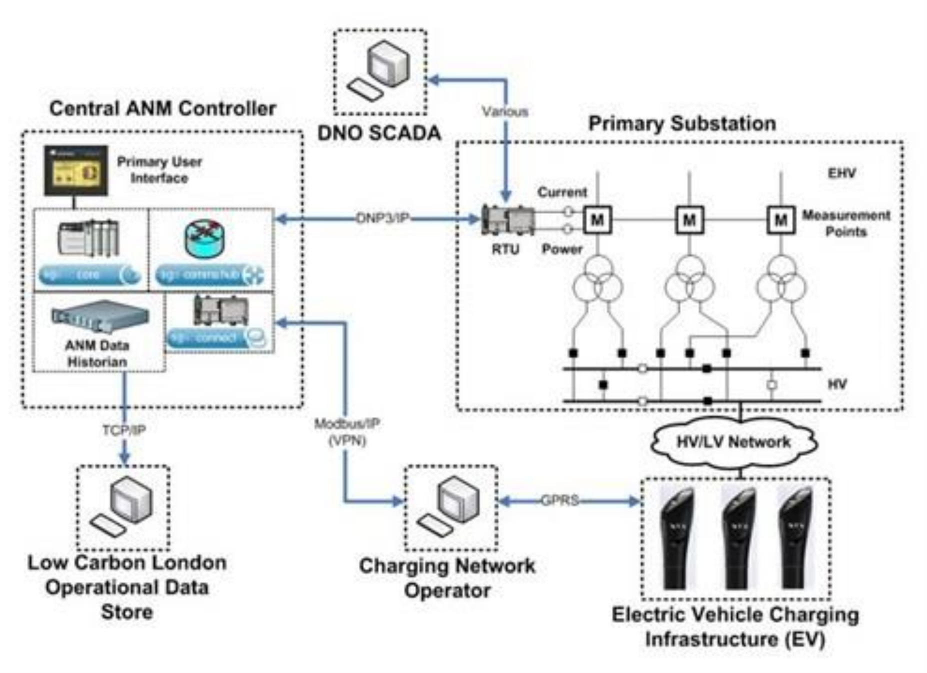

Figure 2 Communication architecture for ANM device employed by trial six

In a domestic situation, there is opportunity to make use of the home area network (HAN) to transfer information to a smart charge station from a local substation device using a secure VPN network.

The trials reviewed have demonstrated that a range of communications solutions can be deployed to deliver DSR for PIV charging. Each have their merits and drawbacks; it has not been possible to identify an obvious solution which would be preferred by DNOs.

Summary: UK and International Trials

- A thorough review of ten UK and international trials has been collated from a cross section of the industry. Trials have employed a wide range of smart charging solutions and illustrate a lack of consensus in agreed communication and targeted demographic.
- ToU tariffs and DSR solutions have been shown to effectively mitigate peak load on electricity networks, although ToU tariffs are reported to be cost prohibitive in GB without roll-out of residential ToU tariffs, including targeted DuoS charges.
- Smart charging solutions are reportedly best suited to domestic properties where charging often aligns with peak demand periods.
- A wide range of communication and connectivity methods have been trialled, each with limitations and advantages. Trials nine and ten have begun developing an interoperable ICT framework for charging and billing control but not yet attempted to develop an industry standard for interoperable smart charging solutions nor have they developed a clear path to acceptance for any method.

4. Options for Managing PIV Charging

This section sets out the results of a review of published information regarding existing technology, communication protocols and Standards for managing PIV charging. The commercial readiness of the technology of a number of these systems varies and is highlighted where appropriate.

4.1 Existing Systems for Managing PIV Charging

This section sets out a review of existing products and technologies that are currently available or can be described as market ready (solution fully developed) for the smart or controlled charging of plug-in vehicles.

The information collected to inform this technological review is summarised in Appendix III, which contains a synopsis of specific smart charge solutions, the information collected includes:

- Product name
- Manufacturer
- Country of Deployment
- Market Availability
- System Installation Point
- Charge Functionality
- Communications and Protocols
- Information Source(s)

The reviewed solutions, presented in Table 2, are representative of the current available market technology and offerings; it does not constitute a complete list.

Table 2 Existing Solutions for Controlled Charging

Manufacturer	Product	Description
Chargemaster[12]	F22	Internet connected controlled charging post. Dual Type 2, Mode 3, socket capable of 3-ph 22kW. OCPP and control.
eo Charging[13]	eo Genius	Internet connected controlled charging station. Type 2 socket, up to 3-ph 22 kW. Mode 3 control.
EA Technology	Esprit	Substation monitoring device capable of remotely switching connected charge stations.
Zaptec[14]	Zapcharger SMART	Internet connected controlled charging station. Type 2, Mode 3 socket, up to 22kW. Highly featured for communication and control.
Rolec[15]	WallPod (Range)	Locally connectable charging stations with central control software. Type 2, Mode 3 Sockets. 1-ph 7kW, 3-ph 22kW.
Various	Smart Meter (SMETS Compliant)	Smart meter equipped with auxiliary load control switches.

The reviewed smart charging solutions sit between the utility infrastructure and the internal PIVs' charging systems. They can receive control instructions from a variety of sources, including the PIV user (common in domestic solutions), a central system (common in public solutions) or the network operator. The exact functions of these devices vary between products but include the following:

- Time Control
- Load Switching
- Remotely Start/Stop Charging
- Load Limit Criteria
- Smart Metering

The method in which these control instructions are communicated also varies between suppliers with some providing limited or no information. However, several communication techniques were identified, as follows:

- PLC Communication
- GPRS
- Ethernet or Wi-Fi internet connectivity
- Bluetooth (Low Energy)
- RFID
- NFC

[12] Chargemaster F22 Specification. Available: https://www.chargemasterplc.com/media/documents/F22_Data_Sheet_Specifications_V02_13-5-14.pdf
[13] eo Charging, eo Genius Specification. Available: http://eocharging.com/wp-content/uploads/2016/01/eoTechnical-Specifications.pdf
[14] Available: http://www.zaptec.com/smart
[15] Rolec EV Charging Equipment. Available: http://www.rolecserv.com/ev-charging

Communication protocol information was limited and varied between suppliers; the use of OCPP (see Section 4.3.1) was advertised by the F22 Chargemaster device.

In terms of physical connectors, the majority of charge stations reviewed, including those capable of smart charge control, were capable of supplying Mode 3 enabled vehicles and fitted with Type 2 connectors. Mode 3 charging uses a dedicated charging station permanently connected to either a single or three phase AC supply network. The mode provides conductors for communication between the vehicle and charging equipment, and for providing dedicated earth protection. The charging supply is not active by default and requires communication over the control pilot to begin. Mode 3 is compatible with Type 2 connectors which includes control and proximity pilot communication pins, these are capable of sensing when a vehicle is connected and communicating the available charging current. This has obvious benefits in a smart charging solution if the available current signal is manipulated.

In addition to charge stations, smart meters are also capable of supporting controlled charging solutions. The Department of Energy and Climate Change requires that all energy suppliers install smart meters as standard by 2020. The functionality of smart meters is described in the Smart Metering Technical Specification[16] (SMETS), endorsed by the UK government. The current iteration (1.58) requires compliant meters to control up to five auxiliary load control switches (ALCS), including those connected to a Home Area Network (HAN). A newer version (SMETS 2) will contain updated requirements and is currently awaiting approval, it will require control of a minimum of five HAN connected ALCS. A HAN connected ALCS (HCALCS) shall be capable of establishing a secure and authenticated communication link with one smart meter, this will constitute both the sending and receiving of commands. One such command shall include the control of a HCALCS, the nature of the control is unspecified. SMETS 2 recommends these are connected to a PIV charging station and other high load appliances. This offers a potential load shifting solution for PIV charging during peak demand periods.

4.2 Standards and regulations applicable to PIV Charging

4.2.1 IEC EN 61851-1:2011 Electric vehicle conductive charging system; Part 1

This Standard applies to on-board and off-board equipment for charging electric road vehicles at AC supply voltages up to 1 000 V and DC voltages up to 1 500 V, and for providing electrical power for any additional services on the vehicle if required when connected to the supply network. The aspects covered include characteristics and operating conditions of the supply device and the connection to the vehicle; operators and third party electrical safety, and the characteristics to be complied with by the vehicle with respect to the AC/DC. EVSE, only when the EV is earthed.

4.2.2 IEC EN 62196-1:2014 Plugs, socket-outlets, vehicle connectors and vehicle inlets; Conductive charging of electric vehicles; Part 1

This Standard is applicable to plugs, socket-outlets, connectors, inlets and cable assemblies for electric vehicles, intended for use in conductive charging systems (as described in IEC 61851-1) which also incorporate pilot control functions.

4.2.3 Other Standards

A number of other Standards apply to the manufacture, installation and operation of PIV chargers. These include EU Standards applicable to electrical appliances[17,18], IET wiring regulations[19] and Code

[16] Smart Metering Implementation Programme, Smart Metering Technical Specifications, V1.58, Available:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381535/SMIP_E2E_SMETS2.pdf
[17] Low Voltage Directive (LVD) 2014/35/EU
[18] Electromagnetic Compatibility (EMC) Directive 2014/30/EU
[19] BS 7671 "Requirements for Electrical Installations"

of Practice on installation of charging equipment[20]. However, these have not been found to impact the uptake of controlled charging systems.

4.3 Protocols for Interaction with PIVs or PIV Chargers

Protocols establish the rules that dictate communication between devices; this section sets out a review of existing communication protocols that are currently available for charging and smart or controlled charging of PIVs.

There are several established protocols for communication between PIVs, charging stations, local control systems and the network operator. These exist to relay critical charging information such as:

- Available charge current
- Battery requirements
- Confirmation of vehicle connection
- Transaction information

The current publicly available charging protocol and communication architecture can be described by the following three protocols:

1. Open Charge Point Protocol (OCPP) (Section 4.3.1)
2. Open Smart Charge Protocol (OSCP) (Section 4.3.2)
3. Pilot Communications Protocol (Section 4.3.3)

Figure 3 illustrates the possible interactions between publicly available protocols. The function of the protocols and brief descriptions of the components within Figure 3 are given below.

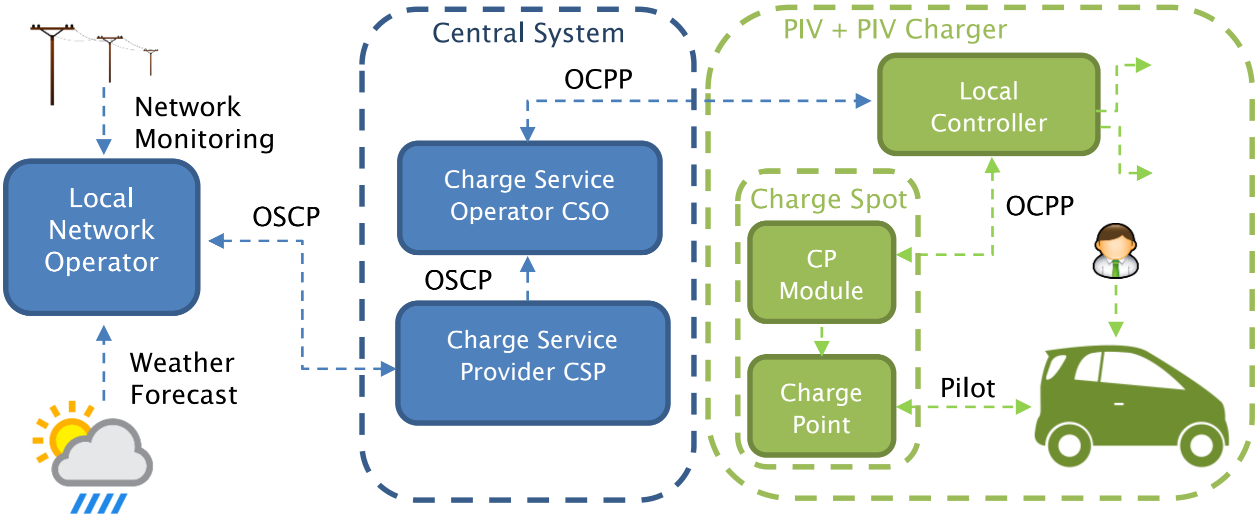

Figure 3 Communication protocol interface

The Local Network Operator (e.g. DNO, IDNO), communicates available network capacity with a Central system, making use of the Open Smart Charging Protocol (OSCP)[21].

[20] IET (2012) "Code of Practice for Electric Vehicle Charging Equipment Installation"
[21] Open Charge Alliance (2015) "OSCP Specification v1.0" Pg. 7. Available: http://www.openchargealliance.org/uploads/files/OSCP_Specification_v10.pdf

The Central System can include the Charge Service Operator (CSO), responsible for operating a network of charge points, and the Charge Service Provider (CSP) responsible for trading the available electricity to customers.

The Central System communicates with the Local Controller using the Open Charge Point Protocol (OCPP) developed by the Open Charge Alliance, which appears to be increasingly adopted, by Charge Point OEMs[22]. The Local Controllers have multiple locally connected charge stations and interpret the OCPP for the charge point. The final protocol exchange makes use of the pilot cable between the charge point and PIV, where charging information is exchanged[23].

OEMs do not readily publicise the protocols employed by their equipment and may operate proprietary protocols which are not publicly available. OEMs can offer additional system communication through smartphone applications, web servers or a physical interaction at the PIV or charge point. This offers an interface for the user to provide preferences to the vehicle such as remote charging functions[24].

4.3.1 Open Charge Point Protocol

OCPP is a set of rules which dictate the interaction between a **Central System** and **Charge Point.** It is designed to allow for any charging mode and interoperability between any central system and charge point, regardless of vendor or OEM. It was developed by the E-laad foundation (now ElaadNl) in 2009, the most recent iteration is OCPP 1.6[25].

- The **Central System** is defined as the Charge Point Management System: The system that manages multiple Charge Points and has the information for authorising users for using its Charge Points.
- The **Charge Point** is defined as the physical system where an electric vehicle can be charged, it may have one or more connectors.

The Charge Point Management System and Charge Point can be within the same device. This is common for stand-alone devices; although it is more common for these to be separate in commercial applications.

The functionality of OCPP can be summarised as follows:

- Confirm a charge point is connected to a live supply and non-faulty
- Communicates transaction information
- Lock and unlock the connector
- Communicate firmware updates
- Remotely reserve charge points
- Communicate Smart Charging information

The full functionality of the protocol can be found in the Open Charge Point Protocol 1.6 document.[26]

The Smart Charging function includes the passing of messages capable of adjusting available current capacity. The PIV is able to respond to this by increasing or reducing power flow whilst charging. The parameters for this function are provided by OSCP (Section 4.3.2).

[22] Open Charge Alliance (2015) “OCPP Specification v1.6” Pg.10. Available: http://www.openchargealliance.org/uploads/files/OCPP_1.6_Specification.pdf
[23] Available: http://www.smartcharging.nl/en/smart-charging/how-does-smart-charging-work/
[24] Available: https://itunes.apple.com/gb/app/nissanconnect-ev/id407497029?mt=8
[25] Open Charge Alliance. Available: http://www.openchargealliance.org/about/background/
[26] Open Charge Alliance (2015) “OCPP Specification v1.6”. Available: http://www.openchargealliance.org/uploads/files/OCPP_1.6_Specification.pdf

Although the transfer of protocol messages must be secure; OCPP 1.6 does not specify the exact communication technology, only requiring support for TCP/IP connectivity[27]. Therefore, security must be provided as an additional layer (e.g. VPN tunnel).

OCPP 1.6 groups protocol features and messages into *profiles.* Charge point OEMs can choose which profiles to implement, the *Core* profile is a minimum requirement. Review of specifications published by Charger OEMs indicates that the majority of OEMs offer features in-line with OCPP, although the details of the implementation are not publicly available. The OCPP profiles are listed in Table 3:

Table 3 **OCPP Profile Grouping**[28]

Profile Name	Description
Core	Basic Charge Point functionality comparable with OCPP 1.5 without support for firmware updates, local authorisation list management and reservations.
Firmware Management	Support for firmware update management and diagnostic log file download.
Local Authority List Management	Features to manage the local authorisation list in Charge Points.
Reservation	Support for reservation of a Charge Point.
Smart Charging	Support for basic Smart Charging, for instance using control pilot.
Remote Trigger	Support for remote triggering of Charge Point initiated messages.

4.3.2 Open Smart Charge Protocol (OSCP)

Open Smart Charging Protocol is an interface between the **local network operator** and the **charge point management system**, designed to provide an agreed protocol for communicating smart charge functions between any equipment. Specifically, OSCP provides a protocol for the local network operator to inform the Charge Point Management System of the available current for connected PIVs, to avoid exceeding safe network capacity at times of high demand[29]. It was developed in coalition between the Dutch charging service provider (CSP) GreenFlux and the Dutch network operator Enexis[30]. OSCP defines the parties as:

- The **local network operator** is the body responsible for the operation and maintenance of the electrical assets for distributing electricity. In many cases this is the licensed distribution network operator (DNO), it may also be an independent operator or customer with their own network.
- The **charge point management system** (central system) is the interface for communicating with all connected local controllers, in turn connected to several charge points.

[27] Open Charge Alliance (2015) "OCPP Specification v1.6". Pg.6. Available: http://www.openchargealliance.org/uploads/files/OCPP_1.6_Specification.pdf
[28] Open Charge Alliance (2015) "OCPP Specification v1.6". p.11. Available: http://www.openchargealliance.org/uploads/files/OCPP_1.6_Specification.pdf
[29] Available: https://www.smartcharging.nl/en/smart-charging/why-use-smart-charging/
[30] Montes Portella, Klapwijk, Verheijen, De Boer, Slootweg, Van Eekelen, 2015, OSCP – An open protocol for smart charging of electric vehicles, *Proceedings Cired Conference 2015*, paper 0106. Available: http://cired.net/publications/cired2015/papers/CIRED2015_0106_final.pdf

Appendix IV summarises the protocol messages and functions provided by OSCP. The following points are an example of the core smart charge control functionality:

- A heartbeat function to provide confidence of an operational charge point and an active communication connection.
- A message allowing the management system to receive and request a capacity value, allowing for PIV charging current to be limited.
- A message allowing management system to provide an aggregated usage value, indicating the energy used to charge a PIV within a specified timeframe, permitting available capacity to be distributed effectively by the DNO.

An example of OSCP functionality combined with the function of OCPP is as follows:

1. The maximum available current for the charger network is communicated to the charge point management system from the network operator (DNO) using OSCP.
2. The charge point management system acknowledges the available capacity and any charge points which require power, the system then determines the capacity allocation. The division of power is at the discretion of the charge point management system operator (CSO).
3. The charge point management system communicates the maximum available current for each charge station to local controllers, making use of OCPP.
4. As network load changes, the capacity value will change, the updated value is communicated to the charge point management system using OSCP.
5. In turn, the maximum available current for each charge station is adjusted to allow the charge point to draw more or less current as required, this is communicated using OCPP.[31]

4.3.3 Pilot Communication Protocol

Pilot communication occurs between the PIV and the Charge Point when using the conductive charging method (tethered connector) for charging modes 2, 3 and 4[32]. The alternative inductive charging method is at the trial only phase in the UK and has no comparable protocol information to date. This communication method requires the tethered connector to include capability for communication signalling, Type 1 and Type 2 charging leads are designed to conform with IEC 62196-1[33] (SAE J1772 (US)) which requires the following cable cores:

- Three phase cores
- Single neutral core
- Single primary earth core
- Two pilot cores for communication:
  - The Proximity Pilot is used for pre insertion signalling
  - The Control Pilot is used for post insertion signalling

Pilot Functionality
According to IEC 61851-1 for PIV conductive charging, pilot communication is mandatory and it **must** provide the following functions between the PIV and PIV charging system:

- Verification that the vehicle is properly connected
- Continuous protective earth conductor continuity checking
- Energisation of the system
- De-energisation of the system.

The following pilot functions are **optional**:

- Selection of charging rate
- Determination of ventilation requirements of the charging area
- Detection/adjustment of the real time available load current of the supply equipment

[31] Available: http://www.openchargealliance.org/uploads/files/OSCP_Specification_v10.pdf
[32] IEC EN 61851-1:2011Section 6.4.5
[33] IEC EN 62196-1:2014

- Retaining/releasing of the coupling
- Control of bi-directional power flow to and from the vehicle

The full pilot protocol function is described in Appendix V.

Example Pilot Process
The following process illustrates the pilot functions by describing the sequence of a PIV connecting to a charge point, charging and disconnecting.

- Charge Point plug is unpowered until vehicle is connected and requesting power
- Charge Point signals the presence of AC voltage
- PIV detects plug via proximity circuit – this prevents drive-away whilst connected
- Control Pilot functions begin:
  - Charge Point detects PIV through proximity
  - Charge Point indicates to PIV it is available to supply power
  - PIV indicates whether ventilation is required (typically for lead acid batteries[34])
  - Charge Point indicates current capacity (see Appendix V for detail)
  - PIV on board charger controls the power used (based on vehicle requirements and the limitation of the charge point).
  - PIV and Charge Point continuously monitor earth continuity
- Charge continues, with power controlled by the PIV
- Charge will stop when interrupted by disconnecting the plug from the vehicle or when the PIV is fully charged

Summary: Options for Managing PIV Charging

- Existing controlled charging systems commonly interact with either local or internet connected charging stations. My Electric Avenue successfully trialled an intermediary device for load management between the charge station and local substation. Communication systems employed by these solutions varied, with no clear path to wide acceptance for any method.

- The functionality of Smart Meters to control HCALCS could be considered as a controlled charging interface. This solution has not been widely applied.

- Communication protocols used across the PIV infrastructure are predominantly proprietary or non-disclosed. The development of open protocols such as OCPP and OSCP allows for system agnostic communication which should lead to wide scale customer acceptance. Pilot communication protocol (Mode 3), as described in IEC-61851-1 is widely utilised.

- There is currently no standard for the controlled or smart charging of PIVs commonly applied across any industry, existing solutions are of varying form and are not interoperable. There is clear need for a standardised approach to controlled PIV charging.

5. Vehicle to Grid

The wider PIV Framework project includes scope for highlighting an upgrade path to incorporate future developments in vehicle to grid (V2G). In order to support that objective, this section briefly highlights relevant learning in this section.

V2G is the process where power from an electric vehicle is transferred from a vehicle's battery to the local electricity network. This process has applications in peak load situations to provide

[34] Available: http://na.bhs1.com/battery-room/ventilation/

demand side response and provides opportunity for PIV owners to sell electrical energy from their car battery in periods of high demand or insufficient supply.

Current trials and technologies are predominantly focussed on controlled charging of PIVs. However, V2G systems have the potential to radically change the landscape of PIV chargers. Particularly if customers, aggregators, or other parties are actively seeking to deliver revenues by offering V2G services.

5.1 V2G Projects

The majority of work in the V2G field is currently at the trial stage. The focus of ongoing trials is on user interface and commercial agreements. The recently launched Nissan-Enel trial[35] will give PIV owners the opportunity to sell back power to energy suppliers and will also assess the feasibility of flexible energy sources for providing smart energy management. The trial will use Nuvve[36] technology to charge and intelligently discharge PIV batteries to respond to load shift requests and price signals. The supplier has indicated that this technology is not commercially available at the time of writing.

5.2 V2G Standards and Protocol

The pilot pin protocol described in Section 4.3 and defined by IEC 61851 includes optional provision for bi-directional power-flow. However, the detail of this control is outside of the scope of IEC 61851. The OCPP and OSCP protocols do not include provision for V2G control. However, there is no fundamental limitation to their inclusion at a later date.

5.2.1 IEC EN 15118-1 Road vehicles – Vehicle to grid communication interface

This Standard specifies the communication between Electric Vehicles, including Battery Electric Vehicles and Plug-In Hybrid Electric Vehicles, and the Electric Vehicle Supply Equipment (EVSE). IEC 15118 set outs a communication framework and use cases to facilitate V2G charging, considering automotive OEM, utility (i.e. DNO) and user requirements.

From the information reviewed in this work, it is not clear to what extent IEC 15118 has been adopted by industry and it is likely that the Standard is under review for further iteration.

5.3 Existing V2G Systems

A review of the publicly available information on this technology found that there are currently no commercially available vehicle to grid solutions in the UK. However, the form and structure of V2G technology can be described: It is likely that a V2G solution will make use of a bi-directional charging station, which is capable of energy flow both to and from the vehicle. Similarly, the vehicle's AC/DC charging inverter will operate in reverse (DC/AC) to provide energy to the grid. At a DC charging point the power inversion would take place off-board. At the point of connection to the existing network, normal distributed generation connection requirements will apply including grid-synchronisation and in the UK compliance with the Energy Networks Association (ENA) Engineering Recommendations G83 for microgeneration, or G59 for larger connections.

An example product in the USA provides bi-directional power flow through the use of a fast DC charging station, the Coritech Services "Electric Vehicle DC V2G Fast Charger[37]".

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[35] Available: https://www.enel.com/en-gb/Pages/media/press/detail.aspx?source=media&id=1572&title=NISSAN%20AND%20ENEL%20LAUNCH%20GROUNDBREAKING%20VEHICLE-TO-GRID%20PROJECT%20IN%20THE%20UK&curPage=1
[36] Available: http://www.nuvve.com/
[37] Available: http://coritech.com/dc-chargers

Summary: Vehicle to Grid

- V2G technology is at the commercial trial stage, the results of the Nissan-Enel trial should be closely monitored to inform likelihood of future acceptance.
- There are currently no commercial examples of a functioning V2G system in the UK. However, the technology is available and the form of the solution is apparent.
- A protocol to enable V2G communication has been standardised in ISO IEC 15118. It is also possible to integrate V2G messages into a controlled charging infrastructure. However, the existing versions of OCPP/OSCP are not capable of this. An industry accepted standardised approach is likely to incorporate facility for V2G solutions.

6. Next Steps for the Smart EV Project

- This report is issued alongside a research paper (Smart EV Deliverable 2) which outlines a roadmap for PIV charging types and locations, based on a series of interviews with key industry stakeholders.
- These two deliverables form the underlying knowledge base from which to develop concept options for a standardised approach to controlled PIV charging.
- Following the collation of an options paper, the Smart EV project will actively consult with utilities, automotive and customer stakeholders to update and select the most viable option for managing PIV charging.

7. Conclusions

C1. A review of trials which considered the impact of PIV uptake has shown that controlled charging solutions can offer a viable and cost effective means of avoiding significant cost to electricity customers due to uptake of PIVs.

C2. Trials have shown the capability for controlled charging using on-vehicle, on-charger and intermediate devices to shift load from PIV charging.

C3. Trial results suggest that smart charging solutions may have greater application for alleviating network load at peak times in a domestic setting, where most vehicles are charging at these times.

C4. ToU tariffs were found to effectively mitigate against peak load stress on electricity infrastructure but DNO roll-out in GB may be prohibited by cost without roll-out of residential ToU tariffs, including targeted DuoS charges.

C5. A range of DSR solutions are available with the capability to limit PIV charging, predominantly located within charge points and provided as an optional item.

C6. Communication and control protocols used by the available DSR solutions are often proprietary. Open protocols (OCPP and OSCP) provide the required functionality for the solutions developed by OEMs and provide system agnostic communications. OSCP/OCPP messages can be communicated using any internet IP based mechanism, trials no particular connection method is favoured or appears best suited from trials and existing systems.

C7. Controlled charging is facilitated by the IEC 61851 Standard for communication between charge point and PIV (Pilot control). This is widely adopted and allows charge points to vary available charge power to the PIV.

C8. The UK government endorsed SMETS 1.58 offers auxiliary load control switches which have capability to switch PIV charging equipment, this has not been widely used to date.

C9. V2G systems are at the later-stage of trials, but existing Standards and protocols do not include provision for the systems. A standalone V2G Standard is available.

C10. The PIV industry has developed and trialled systems capable of delivering controlled charging solutions. However, there is no accepted standardised approach for controlled charging such that a DNO could procure such a service. There is clear need to produce a controlled charging Standard providing system interoperability, allowing wide scale adoption and acceptance by industry and customers.

Appendix I Charging Terminology

This section summarises the definition of the charging modes and connector types on the market.

Charging Modes

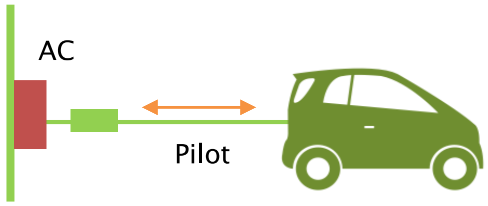
The term ‘Mode’ is used to describe the charging power, protection and interface employed by electric vehicles of varying power requirements. The following definitions are used in accordance with IEC-61851-1-2011[38].

Mode 1 Charging

Connection of the PIV to the AC supply network, utilising standardised socket-outlets not exceeding 16A and not exceeding 250V AC single-phase or 480V AC three-phase, using the power and protective earth conductors. The charging circuit must include earthing, an overload circuit breaker and an earth leakage protection. Due to the low available current this is a slow charging mode, as it usually shares a circuit with other services it can lead to overload tripping. It is prohibited in the US and common for EVs such as Bicycles in the UK.

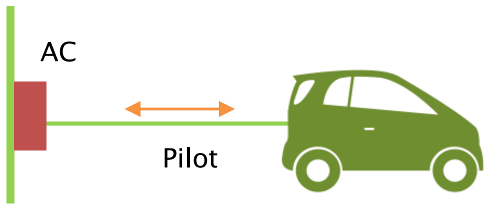
Mode 2 Charging

Similar to Mode 1 charging the PIV is connected to the AC supply network, not exceeding 32A and not exceeding 250V AC single phase or 480V AC three-phase using standard single-phase or three-phase socket-outlets. This mode uses the power and protective earth conductors of the charging system with a control pilot function and system of personal protection against electric shock (RCD) between the PIV and the plug or as a part of an in-cable control box. The inline control box must be located within 0.3 m of the plug or the EVSE.



Mode 3 Charging

Mode 3 uses a dedicated PIV charging station permanently connected to the AC supply network. A control and protection service is permanently installed and a control pilot function extends between control equipment in the charging station and the vehicle. The pilot is capable of transferring control signals to adjust the charge schedule. The charging supply is not active by default and requires communication over the control pilot to begin.



Mode 4 Charging

Mode 4 uses a dedicated PIV charging station permanently connected to the AC supply network. In addition it utilises an off-board charger which converts the AC supply to DC power for vehicle charging. A control pilot function extends to the equipment permanently connected to the AC power supply. The charging cable is rated for high DC power transfer to the vehicle and allows for fast charging, which can be limited by the vehicle’s import capacity.

[38] IEC 61851-1-2011 Section 6.2.

Connector Types

Several connector types, which are prominent in the PIV charging industry are presented below, Table 4 summaries the key charging features and appearance of these connectors.

Domestic

This is a standard domestic electrical socket connection. In the UK this is a single phase, three pin AC power plug, as specified in BS 1363-1:1995, classified as type G by the IEC[39]. Domestic connector types are capable of supplying up to 3kW and are suitable for Mode 1 and Mode 2 charging.

Type 1

The Type 1 connector, also known as the J1772 connector, is designed to meet the requirements of the SAE J1772 standard, adopted by the IEC as IEC-62196. The connector consists of five pins, for the transfer of single phase AC power and control signals. As the pins include primary earth and control conductors, the connector is suitable for Mode 3 charging. As a single phase connector it is only capable of standard charging.

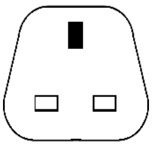
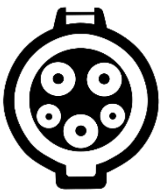
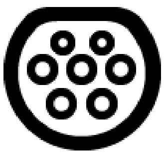
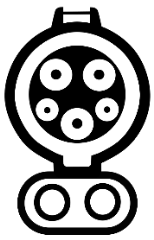
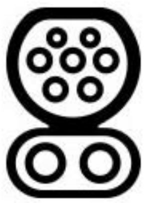
Type 2

The Type 2 connector is also designed to meet the requirements of IEC-62196 for providing Mode 3 charging. The main deviation from the Type 1 connector is the ability to supply three phase power, made possible through two additional phase power pins. The Type 2 connector can supply both single and three phase power and as such is capable of standard, fast and rapid charging, depending on the point of connection.

DC Types

In addition to AC charging connectors, there are several DC connectors to enable DC rapid charging. DC charging is described as Mode 4 by IEC-62196. Mode 4 requirements for control communication echo Mode 3, as such pilot pin conductors are mandatory and a positive and negative DC terminal must be provided. There are two styles of DC connector, the Combined Charging System (CCS) and the CHAdeMO connector. CCS style connectors are developments of the Type 1 and Type 2 connectors to allow for a universal AC/DC charge socket. The CHAdeMO connector is DC specific. These style connectors are capable of Mode 4 charging.

Table 4 Existing Solutions for Controlled Charging

Domestic	Type-1	Type-2	CCS –Type 1	CCS – Type 2	CHAdeMO
AC			AC/DC		DC Three Phase
Single Phase		Three Phase	Single Phase	Single Phase	
Mode 1 / 2	Mode 3	Mode 3	Mode 1 / 2	Mode 3	Mode 3
					

39 International Electrotechnical Commission, World Plugs, Available: http://www.iec.ch/worldplugs/typeG.htm

Charge Type

The PIV industry recognises a wide range of terminology for the description of charging, in some instances, due to branding or varying definitions this can lead to uncertainty. For brevity in descriptions and to assure consistency, Table 5 sets out the parameters which will be used for the definition of charging types.

Table 5 Existing Solutions for Controlled Charging

Charge Term	Standard	Fast		Rapid		“Super Rapid”	
Alternative Terms	Slow Normal	Faster		Quick		“Super-Fast” “Super Charge”	
Power Transfer	≤3kW	≤7kW	≤22kW	≤43kW	≤50kW	>43kW	>50kW
	Single Phase	Single Phase	Three Phase	Three Phase	DC	Three Phase	DC
Typical Charging Time	8 - 12hrs	3 - 4hrs	1 - 2hrs	80% in 20 - 30mins		< 20 - 30mins	

Appendix II PIV Trials

Project 1 - EVCS / ELVIIS

105230 Trial Questionnaire		**1**
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
EVCS / ELVIIS	Ericsson/Göteborg Energi/Volvo/Victoria Institute	2011 - 2013
1.4 Objectives		
• To trial EV with internal charging meter which will allow customers to pay one bill and charge from any outlet. • To trial charge control via in car, smart phone or web interface • To learn if the grid can optimise charging patterns for EVs (Peak load reduction)		
2. Project Specific Questions		
2.1 Scale of Connections	**2.2 Charging Types/Methods**	
Selected families in Gothenburg	Any charging outlet	
2.3 Project Functionality, Protocols and Communication		
The project placed the smart charge control function within the PIV as opposed to the charge point. Allowing the vehicle to smart charge from any 'dumb' outlet, including dedicated charge points. The User then chooses a charge schedule/requirement. The PIV communicates charging demand to a central system which returns a local available capacity and detailed charge schedule. The charge cycle begins. The system communicated using the public mobile network.		
2.4 Evidence of Innovation in Products/Protocol/Communication		
• Modified in-car systems for executing charge schedule, and acting as virtual meter. • Communications over mobile networks, and user interface • EVCS to coordinate communications between user, cars, utility systems, and user devices • Utility to validate cars and charge schedules, and coordinate energy "peak shaving"		
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.		
• Apps for Smartphone, Tablets etc • Web Server		
2.6 Project at Development/Trial/Product Stage		
• Project concluded 2012 • No further developments		
3. Summary		
• Utilities can coordinate EV charging across their region • Users retain control of the charge process and can modify or over-ride it as necessary. • No smart charging pole needed (especially at home for overnight charging) • Uses existing infrastructure – the existing grid and power outlets can be used • Not clear how people avoid being double metered for home charging		
Information Source(s)		
http://www.ericsson.com/res/thecompany/docs/press/media_kits/elviis_content_summary_v6.pdf https://www.viktoria.se/sites/default/files/pub/www.viktoria.se/upload/publications/elviis_final.pdf		

Project 2 - Preparing the Strategic Road Network for EVs

105230 Trial Questionnaire		**2**
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
Preparing the Strategic Road Network for EVs	Highways Agency	2013 -2015
1.4 Objectives		
• Investigate Dynamic battery charging to reduce range anxiety, reduce emissions and minimise impact on road surface. • Reduce environmental impact; improved air quality, reduced noise levels and pollution • Consider the financial charging mechanisms for energy received by EV owners • Identify the additional services to be introduced for added value and operability		
2. Project Specific Questions		
2.1 Scale of Connections	**2.2 Charging Types/Methods**	
N/A	Inductive & Conductive Charging Installed in Road Surface	
2.3 Project Functionality, Protocols and Communication		
• The project was an investigative research study; • Feasibility, off road and on road study of dynamic inductive charging • Development of wireless metering system		
2.4 Evidence of Innovation in Products/Protocol/Communication		
• Dynamic inductive battery charging has not yet been utilised commercially in the UK • A wireless communication method must be used for metering and protocols • There is little evidence of any specific protocol/communication methods being employed.		
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.		
• N/A		
2.6 Project at Development/Trial/Product Stage		
• Project is at research and development stage		
3. Summary		
• The project is to investigate how the strategic road network could support the uptake of EVs by introducing subsurface inductive charging facilities • The project investigates metering solutions for customers • The released material does not discuss 'smart' charging solutions		
Information Source(s)		
http://www.highways.gov.uk/knowledge/projects/preparing-the-strategic-road-network-for-electric-vehicles/ http://assets.highways.gov.uk/specialist-information/knowledge-compendium/2014-2015/Feasibility+study+Powering+electric+vehicles+on+Englands+major+roads.pdf Final Report http://assets.highways.gov.uk/specialist-information/knowledge-compendium/2011-13-knowledge-programme/Preparing the Strategic Road Network for electric vehicles.pdf		

Project 3 - EV Smart Charging Trial

105230 Trial Questionnaire			3
1. General Questions			
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**	
EV Smart Charging Trial	The Mobility House	2014-2015	

1.4 Objectives

- Drivers were able to benefit from the fluctuations in electricity trading prices.
- The intelligent charging station determines the prices on the power exchange each day and uses the information to draw up an optimum charging plan.

2. Project Specific Questions

2.1 Size of Trial	2.2 Charging Types/Methods
11 Participants, Employees of Renault	Renault Zoe Chameleon - 3kW – Rapid Type 2

2.3 Project Functionality, Protocols and Communication

When the Renault ZOE is connected to the intelligent charging station, the charging status is transmitted via the Renault data centre (on board?) to the "swarm management platform" of The Mobility House. The software determines an optimum charging plan on the basis of the fluctuating electricity prices. As soon as the energy can be obtained at a particular price, the charging process starts automatically, without the driver needing to do anything.

2.4 Evidence of Innovation in Products/Protocol/Communication

- The system uses an intelligent charging system, capable of interpreting the car's demand and only providing supply when electricity prices are deemed appropriate.
- The 'smart' system is within the charging device.
- The swarm management platform determines appropriate charging plans based on price.

2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.

- Process takes place without any input from the driver

2.6 Project at Development/Trial/Product Stage

- Trial of technology was recently completed.

3. Summary

- System developed to reduce the electricity charging cost of EVs
- Relatively small trial.
- Made use of a communication system between charge point and a central system with pricing information
- Intelligent charge point set the available charge based on electricity prices
- No interaction with EV operator, system was automatic.

Information Source(s)

http://mobilityhouse.com/en/charge-your-renault-zoe-at-great-rates-and-save-money/

Project 4 - Low Carbon London: Smart EV Charging

105230 Trial Questionnaire		4
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
Low Carbon London: Smart EV Charging	UK Power Networks	2012-2014

1.4 Objectives

- Collect charging profile data to study opportunities for Smart EV charging
- Develop an algorithm to minimise peak demand while respecting the constraints on the user side.
- Case Study of Smart Charging on two fleets of Vehicles

2. Project Specific Questions

2.1 Scale of Connections	2.2 Charging Types/Methods
Fleet of 10 Residential EVs	6.7kWh Avg. (1.23 hours driving Avg.)
Fleet of 22 Residential EVs	5.1kWh Avg. (1.19 hours driving Avg.)

2.3 Project Functionality, Protocols and Communication

- The project collected the charging and driving habits of two fleets of vehicles over 24 hours. An algorithm was then developed to determine if it would be possible to shift EV charging away from peak network demand.
- The algorithm was able to shift demand while vehicles were stationary whilst ensuring the same level of charge was received before the next journey.
- The study retroactively looked at a 24hr period to determine if Smart Charging *could* be used to reduce the network peak. In practice this is not possible, but could be simulated if customers gave a ‘time to next drive’.

2.4 Evidence of Innovation in Products/Protocol/Communication

- The project at this point has focussed on developing an algorithm capable of proving that a correctly applied smart charging mechanism can relieve the network peak demand.

2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.

- N/A

2.6 Project at Development/Trial/Product Stage

- The completed study was a hypothetical task to determine if PIV charging can be controlled to reduce network peak load, without reducing charge available to the customer.

3. Summary

- It was found to be possible to reduce the network peak load of baseline and EV charging without compromising the available charge to the user at each drive event.
- The study was completed retrospectively and not trialled ‘live’.
- Most smart charging actions shift charging demand from peak hours (around 6-8pm) towards the late evening hours
- The potential to shift residential EV charging demand without compromising the users’ journey requirements seems significant.

Information Source(s)

http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20B1%20-%20Impact%20and%20opportunities%20for%20wide-scale%20Electric%20Vehicle%20deployment.pdf
Section 4.6 pg. 53

Project 5 - Low Carbon London; EV Trials: Time of Use

105230 Trial Questionnaire		**5**
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
Low Carbon London; EV Trials: Time of Use	UK Power Networks	2013-2015
1.4 Objectives		
• Investigate the impact of ToU tariffs on domestic customers' recharging behaviour • Use ToU to encourage diversity in EV charging and shifting load to off-peak periods. • Determine charging patterns and if they can be adjusted through the price mechanism.		

2. Project Specific Questions	
2.1 Size of Trial	**2.2 Charging Types/Methods**
10 EV Customers on EDF ECO 20:20 Tariff	Domestic Charge point
58 EV owners as a control group	3.5 – 7.0 kWh
2.3 Project Functionality, Protocols and Communication	
The project installed an EDF ECO 20:20 meter for 10 EV owners, these meters offer consumers a 20% reduced rate between 21:00 and 07:00 and all day at weekends. In addition 58 EV owners were used as a control group to compare charging patterns. Both sets of customers had sub-meters installed to monitor their domestic EV charge point activity. The trial set out to determine if this price control mechanism was enough to shift EV charging to off-peak	
2.4 Evidence of Innovation in Products/Protocol/Communication	
• Use of Economy Tariffs	
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.	
• Advanced knowledge of reduced rates	
2.6 Project at Development/Trial/Product Stage	
• Project Completed	
3. Summary	
• ToU Participants modify their behaviour for a better rate off-peak rate. • If there is no incentive participants plugged in when it was convenient to them. • ToU tariffs do not have to be EV specific to reduce EV load at peak hours, energy suppliers can use existing or planned launch tariffs to achieve this effect. • Results stated DSR was a more effective peak management strategy.	
Information Source(s)	
http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20B5%20-%20Opportunities%20for%20smart%20optimisation%20of%20new%20heat%20and%20transport%20loads.pdf	

Project 6 - Low Carbon London EV Trials: ANM

105230 Trial Questionnaire			**6**
1. General Questions			
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**	
Low Carbon London EV Trials: ANM	UK Power Networks /Pod Point/Smart Grid Solutions	2013-2015	

1.4 Objectives

- Develop an Active Network Management (ANM) system to control a sample of public access charge points.
- Establish a mechanism to curtail charge point demand during times of network constraint
- Evaluate the effectiveness of Smart Charging on creating network relief.

2. Project Specific Questions

2.1 Size of Trial

Charge Points	Sockets	Power
47 – London	94	518KW
05 – City Road B	10	47kW
10 – Newham	20	73kW

2.2 Charge Type

POD Point's EV Controller (Carbon Sync) Integrated with ANM technology from Smarter Grid Solutions.

2.3 Project Functionality, Protocols and Communication

Function

ANM's controller uses a substation monitoring device to measure the load on a substation and regularly polls Carbon Sync (CS), which then controls the amount of charging demand that can be interrupted (shedable load) from the EV charge points connected to that substation. When the substation gets close to its operating capacity, the ANM controller requests CS to shed a percentage of its available "shedable" load, restricting the power supply to the EV charge points.

Protocols/Communication

- Distributed Network Protocol (DNP3) For communication between substation RTU and the ANM controller
- Modbus/IP(VPN) protocol between ANM controller and charge point (Logic controller protocol)
- TCP/IP for transferring data over the internet, from ANM to Data store (Internet protocol)

2.4 Evidence of Innovation in Products/Protocol/Communication

- Substation Monitoring Equipment and Active Network Management (ANM)
- EV Charge Point fitted with EV Controller (CarbonSync)
- Public Charge Points respond to ANM signals.

2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.

- No "*noticeable*" impact on customer service. No interface provided.

2.6 Project at Development/Trial/Product Stage

- Project Completed – products available separately - Carbon Sync, ANM, Charge Points

3. Summary

An innovative trial in the public EV charging space. The trial demonstrated that a combination of ANM and Carbon Sync can provide an automated, real time distribution network load management solution for public access charge points, with minimum impact on EV users. Consideration should be given to the "availability" of EV load on the system.

Information Source(s)

http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20B5%20-%20Opportunities%20for%20smart%20optimisation%20of%20new%20heat%20and%20transport%20loads.pdf

Project 7 - My Electric Avenue

105230 Trial Questionnaire		7
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
My Electric Avenue	EA Technology / Nissan	2012-2015
1.4 Objectives		
• To learn customer driving and charging habits and acceptability of charging curtailment. • To trial equipment to mitigate the impact of EV charging • To explore the network benefits of such technology • To develop a new contractual framework for third party delivery of network innovation projects		
2. Project Specific Questions		
2.1 Size of Trial	**2.2 Charge Type**	
• 10 Clusters of 10 EVs (100 total) in variety of LV networks. • 100 PIV control group • Nissan LEAF cars only	• 3.5kW Rolec Charger • Domestic Charge Points • Six commercial Charge Points	
2.3 Project Functionality, Protocols and Communication		
• The project developed a method for curtailing EV demand at periods when the local LV network was approaching capacity. It has made use of Power Line Communications between substation monitoring equipment and intelligent charging points. • During periods of peak demand, Esprit instigated temporary curtailment of recharging on a 15 minute rolling basis across a cluster of EVs.		
2.4 Evidence of Innovation in Products/Protocol/Communication		
• The trial used an innovative Demand Side Response technology (DSR) called 'Esprit' which monitors the load on the LV cables from the substation and can poll and cyclically switch connected EV charge points during periods of high demand. • The Esprit technology communicated with 'intelligent plugs' through power line communications (PLC).		
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.		
• Customers were able to use the Nissan mobile app to monitor their cars charge level. • Customers did not experience significant loss of service		
2.6 Project at Development/Trial/Product Stage		
• Project Concluded. No product released as yet. • Follow Up Projects – Smart EV and CarConnect (public-facing name 'Electric Nation').		
3. Summary		
• The study into driving/charging habits found that 32% of the UK LV network will require intervention when 40-70% of customers own EVs. • The Esprit technology was successful in curtailing charging when necessary, and therefore has the potential to be a solution for DNOs, as an alternative to network reinforcement. • Customers were widely accepting of the smart charging technology and would be happy to use such a function.		
Information Source(s)		
http://myelectricavenue.info/sites/default/files/My%20Electric%20Avenue%20%28I2EV%29%20-%20Project%20Summary%20Report.pdf		

Project 8 - PIV Charging Pilot Program

105230 Trial Questionnaire		8
1. General Questions		
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**
PIV Charging Pilot Program	Pepco/Itron/Clipper Creek	2013-2015
1.4 Objectives		
• DNO test demand response and calculate the load impact of each event on the network. • Validate EV smart charging stations to support consumer engagement, demand response, time-of-use rates and embedded revenue-grade metering.		

2. Project Specific Questions	
2.1 Size of Trial	**2.2 Charge Type**
• 154 Enrolled participants • 84% PIV TOU Tariff • 16% Whole House TOU Tariff	• Clipper Creek Smart Charging Station installed with Itron embedded metering and ZigBee smart charging protocol • Or, domestic charge point with additional meter installed.
2.3 Project Functionality, Protocols and Communication	
• Enrolled customers were offered a whole house ToU tariff or a PIV only ToU tariff with an additional meter. Those opting for the PIV TOU tariff were able to choose to use either there existing charge point with an additional meter installed or to make use of the 'special' Itron enabled charge point with metering function. • The Itron meter contains ZigBee Smart Energy communications and WiFi connectivity. It is also integrated into Itron's OpenWay network- allowing for smart grid control.	
2.4 Evidence of Innovation in Products/Protocol/Communication	
• Revenue grade measuring equipment, allows for the DNO to accept the metering values provided by the charge point. • Embedded Sensing Technology from Itron, used to measure power flow and command and control communication	
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.	
• Time of Use tariff for whole house or Time of Use Tariff for PIV	
2.6 Project at Development/Trial/Product Stage	
• Trial has been completed and Pepco are currently offering a Whole House time of use trial to plug in vehicle owners, with cars registered within the license area.	
3. Summary	
• The pilot program showed that plug-in vehicle customers predominantly charged at off-peak charging times; thus, confirming that TOU rates are an effective way of changing customer behaviour and reducing load during peak periods. • The outcome of the trial has been for Pepco to offer a whole house TOU tariff to encourage off-peak PIV charging. This suggests that the Itron smart charging meter equipment has not yet been accepted commercially.	
Information Source(s)	
https://www.itron.com/na/productsAndServices/Pages/Electric%20Vehicle%20Smart%20Charging%20Station.aspx http://www.pepco.com/energy/blueprint/pluginveh/ http://www.transmissionhub.com/articles/2016/02/through-december-2015-pepco-s-plug-in-vehicle-pilot-program-had-154-enrolled-participants-in-maryland.html http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002007478	

Project 9 - The Green eMotion

<table>
<tr><th colspan="2">105230 Trial Questionnaire</th><th>8</th></tr>
<tr><th colspan="3">1. General Questions</th></tr>
<tr><th>1.1 Project Title</th><th>1.2 Delivering Body</th><th>1.3 Project Timescale</th></tr>
<tr><td>The Green eMotion</td><td>EU Commission – The Green eMotion</td><td>2011-2015</td></tr>
<tr><th colspan="3">1.4 Introduction and Scope</th></tr>
<tr><td colspan="3">The Green eMotion project is a large EU funded project to promote the uptake of electromobility through EVs. The project consisted of 11 work packages (WPs) to determine how to ensure cross-border use of EVs, including social acceptance of EVs and the economics of problem free billing. The project had particular focus on developing uniform EU-wide processes, standards and IT solutions for charging infrastructure across Europe.</td></tr>
<tr><th colspan="3">2. Project Specific Questions</th></tr>
<tr><th colspan="3">2.1 Size of Trial</th></tr>
<tr><td colspan="3">42 partners from industry, the energy sector, electric vehicle manufacturers, and municipalities as well as universities and research institutions</td></tr>
<tr><th colspan="3">2.3 Relevant Work Packages</th></tr>
<tr><th>WP3 – ICT Solutions</th><th colspan="2">WP7 – Harmonisation of technology and standards</th></tr>
<tr><td>ICT is seen as the key enabler for electromobility, offering a multitude of basic and advanced services to the driver. The integration of these services will allow the usability for the end user without regional limitations (e.g. with roaming or public charging services) and will enable the realization of economies of scale for advanced service offerings like fleet management.</td><td colspan="2">The harmonisation of standards is an essential issue for the mass rollout of EV and PHEV (plug-in hybrid electric vehicle) across the EU. Based on the requirements of the other WPs and the experiences made in the demonstration regions, WP7 considered the standardization efforts for the three layers: vehicle, infrastructure and communication</td></tr>
<tr><th colspan="3">2.4 Key deliverables</th></tr>
<tr><td colspan="3">• 3.10 ICT Standards and Protocols 2
Focuses on the development of interoperable ICT Standards and protocols, leading to the formation of eMI3. Briefly identifies Smart charging options via EVSE or Automotive OEM backend.
• 7.8 Guidelines for Standards and Interoperability
Detailed analysis of existing standards and regulation with gap analysis and roadmap for future development. Smart charging is identified as having a gap in standards, expected to be met by 2020, communications standards referenced include OCPP/OSCP; eMI3 standard; ISO/IEC 15118
• 11.8 Final publishable summary report
A collated summary of the projects key deliverables.</td></tr>
<tr><th colspan="3">2.6 Project at Development/Trial/Product Stage</th></tr>
<tr><td colspan="3">• Project completed and majority of results published.</td></tr>
<tr><th colspan="3">3. Summary of Final Report (relevant points)</th></tr>
<tr><td colspan="3">• Acceptance of EVs can be increased through demonstration of system interoperability and standard connectors; increasing convenience.
• EVs have lower environmental impact than traditional combustion vehicles.
• Smart Charging can reduce the need for grid reinforcement.
• The development of open access public charging infrastructure is mandatory for the mass roll-out of EVs. This requires acceptance of an independent ICT system between all parties.
• The eMI3 group is established to produce an agreed ICT format.</td></tr>
<tr><th colspan="3">Information Source(s)</th></tr>
<tr><td colspan="3">http://www.greenemotion-project.eu/home/home.php
http://www.greenemotion-project.eu/upload/pdf/deliverables/D3_10-ICT-Standards-and-Protocols-2_submitted.pdf
http://www.greenemotion-project.eu/upload/pdf/deliverables/D11_8-Final-publishable-summary-report-V1_4.pdf</td></tr>
</table>

Project 10 – EMI³

105230 Trial Questionnaire			**8**
1. General Questions			
1.1 Project Title	**1.2 Delivering Body**	**1.3 Project Timescale**	
EMI³	ERTICO – ITS Europe	2015 -	
1.4 Objectives			
• "To harmonise ICT data definition, formats, interfaces and exchange mechanisms in order to enable a common language among all ICT platforms for electric vehicles (globally)."[40] • This will enable interoperability of all EVs with any charge point system operator and charge service provider and encourage the uptake of EVs by removing charging barriers (contracts with specific charging vendors). • Intent is that EV users should be able to use any charging point regardless of which service they subscribe to			
2. Project Specific Questions			
2.1 Size of Trial	**2.2 Charge Type**		
• 40 members including Automotive, Charge Point OEMs, energy suppliers and other interested parties	• N/A		
2.3 Project Functionality, Protocols and Communication			
• Developed specification for ICT interface terms and definitions			
2.4 Evidence of Innovation in Products/Protocol/Communication			
Interoperability in the charging market including: • Charge point technical and functional features (connections and ease of use) • ICT systems, communications and data exchange • Business and legal cases.			
2.5 Customer Interface Solution? e.g. Mobile App, Web Server etc.			
• N/A			
2.6 Project at Development/Trial/Product Stage			
• Ongoing			
3. Summary			
Work is ongoing, the group has identified the following challenges to solve: • Establish a fair business case for all actors in the (charging) market • Define clear interoperability rules with evidence (between EVs and charging equipment) • Ensure pan-European coherent and equivalent service level (for customers)			
Information Source(s)			
http://emi3group.com/ http://xwp4f3h137o27oft81jv1nyh.wpengine.netdna-cdn.com/wp-content/uploads/sites/5/2015/11/eMI3-Electro-Mobility-Interoperability-Challenges-v1.0.pdf			

[40] http://emi3group.com/

Appendix III Reviewed Technology

Product	**Manufacturer**	**Country Roll Out**
F22	**Chargemaster**	UK
Market Availability		
Commercially available - Public and Commercial Sector product		
System Installation Point		
Charge Point, Central System		
Charge Functionality		
Dual type 2 socket, each 3-phase and capable of up to 22kW. Suitable for mode 3 enabled vehicles. Function for host to select allowed charging times.		
Communications and Protocols		
OCPP 1.5 Enabled. Communicates over the GPRS or Ethernet connection to the internet with a central system for transaction information, permitted charging times and remote management.		
Source		
https://www.chargemasterplc.com/media/documents/F22_Data_Sheet_Specifications_V02_13-5-14.pdf		

Product	**Manufacturer**	**Country Roll Out**
eo Genius	**eo Charging**	UK
Market Availability		
Commercially Available - Advertised to domestic and public		
System Installation Point		
Charge Point, Cloud Platform (Web Based customer interface)		
Charge Functionality		
3.7kW, 7kW and three phase 11kW and 22kW type 2 charge connectors.		
Communications and Protocols		
Cloud platform allows user to manage charging, view usage pay/find chargers. The device makes use of either SIM or cable Ethernet connections. User can set limits to avoid peak times (common for multiple charge points being controlled by one user).		
Source		
http://eocharging.com/wp-content/uploads/2016/01/eoTechnical-Specifications.pdf http://eocharging.com/genius/		

Product	Manufacturer	Country Roll Out
Esprit	**EA Technology**	UK
Market Availability		
Not Commercially Available		
System Installation Point		
Substation Device and Intelligent Socket at Charge Point. Rolec 3.7kW Charger used in trial		
Charge Functionality		
Provide relief to local LV network by reducing load at peak times. The product was used to monitor LV networks and EV charging points and dynamically prevent charging from overloading the network during peak load periods. The devices communicated using powerline communications and the 'smart control' function was within the substation device. The smart control consisted of cyclic switching of charge points to prevent network overload.		
Communications and Protocols		
Powerline communications		
Source		
https://www.ofgem.gov.uk/ofgem-publications/100342		

Product	Manufacturer	Country Roll Out
Zapcharger SMART	**Zaptec**	Global
Market Availability		
Commercially Available		
System Installation Point		
Charge Point (User interface)		
Charge Functionality		
Capable of delivering all charge levels up to three phase 22kW. Type 2 Mode 3 Charger.		
Communications and Protocols		
Wide range of communications available. Cloud based web server and smartphone app, Bluetooth, NFC and RFID and Wi-Fi and PowerLine Communications. Communication agnostic. Advertises communication between PIVs, other Zaptec SMART chargers, users and the power grid. Protocol information not clear. A highly featured product which is communication agnostic, likely to fit into any eventual market. Includes metering function for commercial application- as charger can communicate with other SMART chargers and control/vary charge rates to protect local infrastructure, the devices meter on energy transferred rather than time connected.		
Source		
http://www.zaptec.com/smart		

Product	**Manufacturer**	**Country Roll Out**
WallPod: EV Ready, EV Home Charge, EV Commercial Charge, Superfast	**Rolec**	Global
Market Availability		
All commercially available products (EV Ready & Home - Domestic)		
System Installation Point		
Charge Point		
Charge Functionality		
Type 1 and Type 2 available, Modes 2 and 3. Up to 20kW.		
Communications and Protocols		
EV: Auto Charge is OCPP. No Load management capability available as standard. Some models offer charging timers and customer override in domestic market. EV ControlCentre can manage the charging of 18 locally connected vehicles.		
Source		
https://issuu.com/www.rolecserv.com/docs/16pp_a5_ev_mini_brochure_2015_-_sin		

Product	**Manufacturer**	**Country Roll Out**
Smart Meter; SMETS 2.0	**N/A**	UK
Market Availability		
Technical Specification Requirements for Smart Meters for Electricity Suppliers to install as standard from 2020, no obligation to install one.		
System Installation Point		
Customer Smart Meter		
Charge Functionality		
SMETS 2 requires as a minimum that an electricity meter must support at least five HAN-connected Auxiliary Load Control Switches – with manufacturers able to support more at their own discretion. This decision was based on discussion with industry representatives who demonstrated this would provide flexibility to cover existing uses and additional capacity for future uses. In addition, one HAN-connected ALCS may connect to multiple devices responding at the same time, for example two electric vehicle charging points. In parallel, there is support for the use of CADs. Allowing the consumer to control devices based on price signals and other triggers should also provide another route for the future flexible use of energy.		
Communications and Protocols		
HAN interface for at least five ALCS. Secure HAN. Methods are left to manufacturer discretion, the technical requirements are listed in the specification.		
Source		
Smart Metering Implementation Programme, Government Response to the Consultation on the second version of the Smart Metering Equipment Technical Specifications Part 2. Pg. 26. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209840/SMIP_E2E_SMETS2_govt_consultation_response_part_2_final.pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68898/smart_meters_equipment_technical_spec_version_2.pdf		

Appendix IV OSCP Functionality

Protocol Message	From	To	Notes
UpdateCableCapacityForecast	Local Network	CSP	Sends the forecast cable capacity. The operator may reserve some additional capacity which can be requested if necessary.
GetCapacityForecast	CSP	Local Network	Requests an UpdateCableCapacityForecast message be sent.
RequestAdjustedCapacity	CSP	Local Network	Requests additional capacity in the case where forecast capacity is not enough. The request can be denied if more than available is requested. This message can also be used to reduce allocated capacity if it is too much.
UpdateAggregatedUsage	CSP	Local Network	This communicates the total usage per CSP to the local network. It is used to check parties have not used too much/little.
Heartbeat	Local Network	CSP	This is to confirm the forecasting algorithm is still running and forecasts are being periodically sent. This can also monitor which CSPs are (not) functioning.
ResponseMessages	Local Network/CSP	Local Network/CSP	Takes a standard form to confirm messages have been either successfully received, failed, not allowed/implemented of an error occurred.
SetChargingProfile	CSP	Local Controller	Send the available charging information to connected LCs.
MeterValues	Local Controller	CSP	Informs CSP of charging status of connected points. Can be used for metering purposes and also informs CSP algorithm when vehicles are charging ‘tail’ using reduced power.

Appendix V Pilot Function and Signalling

Pilot Functions as BS EN 61851-1 for Modes 2, 3 and 4			
6.4.3 Details of functions for modes 2, 3 and 4		**6.4.4 Details of Optional functions**	
6.4.3.1 Verification that the vehicle is properly connected	The EVSE shall be able to determine that the connector is properly inserted and connected. **Vehicle movement by its own propulsion system shall be impossible** as long as the vehicle is physically connected to the EVSE.	**6.4.4.1 Determination of ventilation requirements during charging**	If additional ventilation is required during charging, charging shall only be allowed if such ventilation is provided.
6.4.3.2 Continuous protective earth continuity checking	Equipment earth continuity between the EVSE and the vehicle shall be continuously verified.	**6.4.4.2 Detection/adjustment of the real time available load current of EVSE**	Means shall be provided to ensure that the charging rate shall not exceed the real time available load current of the EVSE and its power supply.
6.4.3.3 Energization of the system	Energisation of the system shall not be performed until the pilot function between EVSE and EV is correctly established. Energisation may also be subject to other conditions being fulfilled.	**6.4.4.3 Retaining/releasing of the coupler**	A mechanical means shall be provided to retain/release the coupler.
6.4.3.4 De-energization of the system	If the pilot function is interrupted, the power supply to the cable assembly shall be interrupted but the control circuit may remain energized.	**6.4.4.4 Selection of charging rate**	To ensure that the charging rate does not exceed the rated capacity of the a.c. supply network (mains), vehicle or battery capabilities.
		6.4.4.5 Details of optional functions for mode 3	Bi-directional power flow requires additional control functions that are not treated in this edition.

Pilot Signal Generation

The circuit for generating the control signal is illustrated in Figure 1. The signals generated by the control pilot are summarised in Table 1.

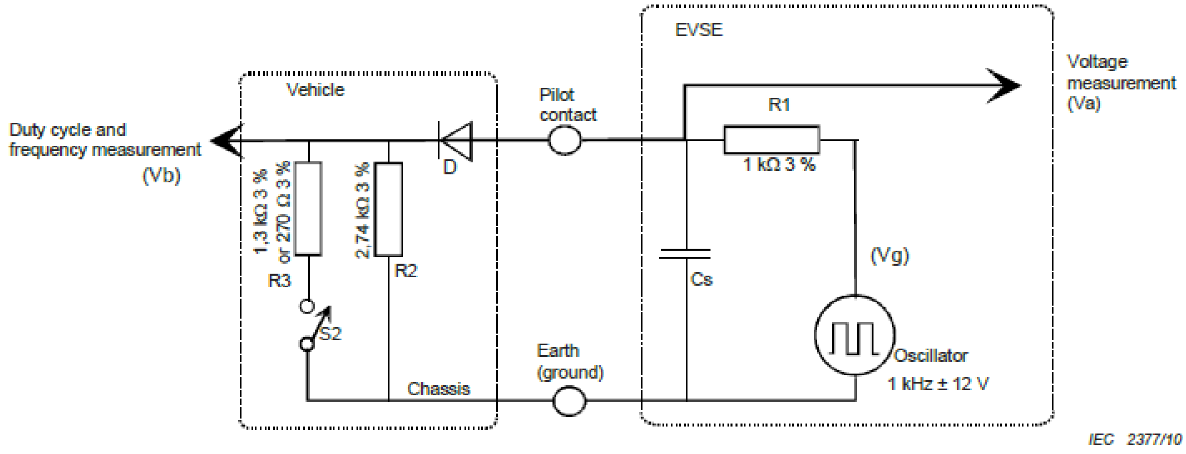


Figure 1 Example control pilot circuit as defined by IEC EN 61851[41]

The PIV determines if it requires power flow and at what rate; batteries close to full charge will require a reduced power flow compared to those with low charge. The power flow rate is not communicated to the PIV Charger. If the vehicle chooses to accept power it closes an internal switch (S2 below) which introduces a parallel resistor, depending on the size of this resistor the measured voltage drops to either +6V or +3V. Dropping to 3v indicates the cars batteries require ventilation during charging as they can release hazardous gases (Lead Acid Cell). When the PIV is fully charged the S2 switch is opened, this raises the voltage to 9V and stops the charging operation.

Base status	Charging status	CP-PE - R2	R3	Voltage, CP-PE
Status A	Standby	Open, or ∞ Ω		+12 V
Status B	Vehicle detected	2740 Ω		+9±1 V
Status C	Ready (charging)	882 Ω	1300 Ω	+6±1 V
Status D	With ventilation	246 Ω	270 Ω	+3±1 V
Status E	No power (shut off)			0 V
Status F	Error			−12 V

Table 1 Control Pilot Signals

Pilot duty cycle provided by EVSE

Available line current	Nominal duty cycle provided by EVSE (Tolerance ± 1 percentage point)
Digital communication will be used to control an off-board DC charger or communicate available line current for an on-board charger.	5 % Duty Cycle
Current from 6 A to 51 A:	(% duty cycle) = current[A] / 0.6 10 % ≤ duty cycle ≤ 85 %
Current from 51 A to 80 A:	(% duty cycle) = (current[A] / 2.5) + 64 85 % < duty cycle ≤ 96 %

[41] IEC 61851-1 pg33. Annex A.

Maximum current to be drawn by vehicle

Nominal duty cycle interpretation by vehicle	Maximum current to be drawn by vehicle
Duty cycle < 3 %	Charging not allowed
3 % ≤ duty cycle ≤ 7 %	Indicates that digital communication will be used to control an off-board DC charger or communicate available line current for an on-board charger. Digital communication may also be used with other duty cycles. Charging is not allowed without digital communication. 5 % duty cycle shall be used if the pilot function wire is used for digital communication
7 % < duty cycle < 8 %	Charging not allowed
8 % ≤ duty cycle < 10 %	6 A
10 % ≤ duty cycle ≤ 85 %	Available current = (% duty cycle) x 0.6 A
85 % < duty cycle ≤ 96 %	Available current = (% duty cycle - 64) x 2.5 A
96 % < duty cycle ≤ 97 %	80 A
Duty cycle > 97 %	Charging not allowed
If the PWM signal is between 8 % and 97 %, the maximum current may not exceed the values indicated by the PWM even if the digital signal indicates a higher current.	

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