WESTERN POWER DISTRIBUTION

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NEXT GENERATION NETWORKS

LV PLUS

CLOSEDOWN REPORT

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Contents

Executive Summary

The LV Plus project aimed to tackle the challenges of increasing demand for power in residential networks that DNOs are facing. The project proposed running the single-phase LV distribution network at a voltage of 400V and using the Power Electronic Converter (PEC) to step LV supply voltage down to 230V at the customer's connection. An earlier Technology Strategy Board (TSB) Feasibility Study suggested it would be possible to increase capacity by 62% at approximately a third of the cost of reinforcement using this method.

The project aimed to specify, design, test and build prototypes to enable a detailed site trial to be carried out to evaluate the PEC performance in normal operation. Key to the design was the use of silicon carbide (SiC) devices which are rated for high power operation. A functional specification defined the maximum, peak and continuous rating and the intended physical dimensions of the enclosure of the PEC was developed. The protection requirements for the PEC were defined so that it effectively coordinated with the miniature circuit breaker (MCB) protection within residential customers' consumer units.

Initial prototypes used SiC devices in an AC chopper design. These failed, experiencing problems which included (a) the current measurement was especially sensitive to noise leading to instability (b) the impact of parasitic loads due to switching rates, (c) the clamp circuit long discharge times resulted in staggered increases in the voltage, (d) difficulty in controlling the circuit at low load and (e) various elements in the design which lead to repeated tripping of the circuit. Due to the failure of the initial SiC designs, the site trials were cancelled and efforts concentrated on alternative designs and topologies.

An innovative circuit design using GaN devices in smaller flat pack packages was developed. This design combined with a unique switching control sequence at 250kHz, resulted in a stable 2.5kW module operating at 350Vac input, 230Vac output and an efficiency of 98%. With further development funding, the key consortium partners estimate it is feasible for this prototype to be developed to a suitable level for full site trials within 3 years.

Analysis of stakeholder functionality requirements was carried out and this indicated that 60% of these could be met without modifying the PEC functionality. The study also concluded that within the UK the current PEC functionality is best suited to medium energy consumers. The best global opportunities to exploit the technology exist in the Western Europe and the Asia- Pacific region due to synergies in network design, size of population and the take up of Electric Vehicles (EVs).

In conclusion, the principle of reducing network capacity using PECs remains viable. The alternative GaN design shows stable performance and addressed the problems encountered with the earlier SiC designs. Further development is required for the GaN design to be used in full site trials and wider implementation.

1 Project Background

A key challenge facing the UK Distribution Network Operators (DNOs) today is the increasing demand for power being placed on residential networks e.g. by the proliferation of electrical vehicles (EVs) and the move to electro-heat. The increase in distributed generation (DG) in areas of network conventionally designed for supplying demand can lead to local voltage rises limiting capacity.

The project proposed the use of a higher AC phase voltage (400V phase to neutral) on the existing LV residential network to increase capacity. The LV Plus project followed on from an earlier TSB Feasibility Study that suggested it would be possible to increase capacity by 62% at approximately a third of the cost of reinforcement. This would be made possible by deploying PECs (Power Electronic Converters) to provide sinusoidal 230V at a customer's premise. However, this application would require the PEC to be approximately 99% efficient to avoid over heating the meter box. This level of efficiency would not be possible with existing power electronics and would require new SiC power electronics as the core enabling technology on the LV grid. The project aimed to develop a prototype PEC, that would be a suitable device to be installed in the customer's property on their side of the cut out, which would be at a sufficient Technology Readiness Level (TRL) to enable large scale trials and commercial launch within three years.

The project partnership comprised Schneider, Exceptions EMS, Turbo Power Systems (TPS), Anvil Semiconductors and Aston and Loughborough Universities (due to personnel moving from Aston to Loughborough during the project). Exception EMS acted as the project lead for the Innovate UK funded project works.

2 Scope and Objectives

The scope of the project was to have developed a prototype PEC device that would fit into existing meter boxes and which could be at a sufficient Technology Readiness Level TRL to enable large scale trials and commercial launch within three years.

The objective was that the completion of the project combined with the individual partners' expertise would enable the ideas and products developed to be adapted for almost any LV distribution network.

Objective	Status
Development of a prototype PEC device at a sufficient Technology Readiness Level (TRL) to enable trials	✗
Increased knowledge and expertise in the use and performance of power electronic converters	✓

3 Success Criteria

Success Criteria	Status
Develop a performance specification for the system	✓
Carry out R&D of different control and protection strategies to meet regulatory/H&S requirements.	✓
Develop and build a number of new 3C SiC MOSFETs	✓
Design, build and test a few different prototype PECs	✓
Identify, design and build a test network for the PEC system trials	×
Validate the trial data	×
Devise a road map for future functionality and commercial development.	✓

4 Details of Work Carried Out

The project aimed to develop a power electronic converter (PEC) that could be integrated safely into a meter box.

Work Package 1:
Work package 1 covered the overall Project Management and was led by EMS Exception. This work package aimed to ensure all necessary planning, coordination, monitoring and review as required by the Innovate UK funding process was carried out.

Work Package 2:
Work package 2, originally led by Aston University prior to personnel moving to Loughborough University, gathered information and data about the functionality required and intended use of the PEC. Additionally, as part of this work package, it ensured that information was disseminated internally within the project group. Dissemination of information to the wider industry was covered by Work Package 14. A few workshops were which the key design and operating principles were agreed which fed forward into the technical specification.

Work package 3:
This work package, led by Aston University, defined the maximum, peak and continuous rating as well as the intended physical dimensions of the enclosure of the PEC. The specification also defined the allowable input and output THD outlining the principles by which the PEC would operate in low voltage conditions. The design specification was developed based on data gathered and the principles agreed in work package 2.

This work package also looked at the possible functions that a PEC would require within Smart Grid applications and the related standards that might apply. The work was a research study that looked at the definitions and functions of smart grids. A technical report was produced by Aston University titled, “Power Electronic Converter (PEC) – Smart Grid Functions” which detailed the findings.

Work package 4:
Work package 4, led by Aston University, developed the necessary protection strategy for the PEC to ensure safe operation in fault conditions and a high-level protection specification was produced, thereby building on and extending the technical specification (WP3) and early project data capture (WP2). The intention was that the existing protection within a customer’s property would remain unchanged and therefore the new PEC had to coordinate with these existing devices. The assumption was made that the PEC would only be fitted to houses with modern consumer units and MCBs installed. The work identified that problems occur if the PEC must coordinate with the overload region of the consumer’s MCBs. A test specification to verify the protection coordination between the PEC and different specification MCBs was produced. This would have been the basis that the prototype (developed in WP6) would be tested against to verify the design. Work was also carried out to determine the most appropriate protection coordination between the PEC and consumer’s MCBs

and a technical specification produced detailing the protection functionality required. This information would have been used in WP10 to verify the suitability of trial locations if these had gone ahead.

Work Packages 5 & 6:
Work packages 5 and 6, led by TPS, aimed to design, build and test a benchmark PEC using proven semiconductors manufactured by Cree. This PEC was based on the function and protection specification developed in WP3 and WP4 respectively. It was intended that this would lead into the development of a prototype design for manufacture and test. The intention has been to carry out multiple iterations with full tests to maximise performance and reduce the cost of the PEC. The rationale was to develop the AC/AC Chopper design using Cree MOSFETS and diodes as they were a known entity and then benchmark the AC/AC chopper circuit that used the Anvil Semiconductor devices against the Cree solution. The intention had been to develop a 5kW prototype, then optimise the design to achieve the necessary 20kW output within the existing meter box foot print. The initial 5kW prototype design experienced a catastrophic failure of the key components during a functional test. The 20kW prototype experience problems with control and the size of the passive filter component. These challenges led to the fundamental rethink of the design and this redesign work proceeded in conjunction with work package 9. The main work on the mechanical design was to ensure the dissipation of the heat from the power circuits without exposing consumers to hot metal surfaces, whilst ensuring suitable safety features provided adequate protection against electric shock.

Anvil Semiconductors' aim as part of the project was to grow SiC on a silicon substrate which would be result in cheaper devices than the Cree devices which were SiC devices on ceramic substrates. Anvil had previously developed a technique that should have addressed the thermal issues on within the silicon substrates. Anvil intended to develop diodes initially and then move on and produce MOSFETs but at no time in the project were they able to achieve results even at the diode level. However, useful results on the impact that the packaging of the devices had on the overall performance were achieved in WP15.

Work package 7:
Work package 7, led by Schneider, aimed to understand the implications for the use of the PEC in wider Smart Grid Applications. It comprised of two elements. The work looked at areas within network and control that the PEC might be suitable such as voltage optimisation, active network management and bidirectional power flows. The work aimed to identify regulatory and network evolution scenarios and then evaluate the potential for these scenarios to affect the positioning of the PEC in the LV network. Work package 7 analysed the report Future Energy Solutions (FES), published by National Grid annually, which attempts to identify future energy solutions within the UK from now until 2050 and uses both economic and environmental indices in the assessment. The report identified four scenarios – Consumer Power, Two Degrees, Stead State and Slow progress. A review of how these scenarios might impact the benefit/payback of the PEC being installed in houses found that the Consumer Power

and Slow progress scenarios would have similar effects on the requirements and benefits for the PEC.

Work package 7 also evaluated the PEC functionality (identified in WP2 and WP3) with a view to understanding the level of uptake that each function might have with the key stakeholders namely distribution (DNO), local markets (DSO) and consumers. Account was taken of the scenarios above because they had different bearings on the likelihood of take up of any function by the stakeholders. Using a weighted scoring method, the PEC functions were assessed to determine which functions provided the greatest benefit to each of the stakeholders for a given scenarios. The findings were detailed in a report by Schneider, “Delivering a Low Cost, High Capacity, Smart Residential Distribution Network: Final report”.

Work package 8:
Work package 8, which was led by Schneider, aimed to understand what PEC functionality would be required for the future needs of the DNOs as the networks change and built on the work carried out in WP 7. It also aimed to consider what the changing DNO models and European and Global markets might require from the PEC. The package focused on two key work streams. Firstly, it considered what variations in PEC functionality would be required for different network arrangements, for example, urban or rural networks. It then considered what variations in functionality might be required for different European and Global networks how the development of the PEC might evolve to maximise this future market potential.

Schneider carried out work to better understand the potential functional variations that might be required the different types, or classes, of domestic customers were reviewed based on Elexon’s Class 1 users, which covers domestic unrestricted consumers, and OFGEM TDCV’s Class 1, which covers domestic single rate meter users. These were found to align well and provide three classes of domestic consumer based on energy usage. Schneider evaluated the potential PEC functionality identified in WP7 for the three classes of energy consumers and found that the present functionality within the PEC best suited Class 2 users who were medium energy use (between 1900 and 2100 kWh/year) and often medium sized properties (semidetached), usually with two adults and two children who are not likely to be home during the day.

Schneider’s review of the requirements for European and Global markets focused on countries that had potential growth in smart grid technologies and electric vehicles whilst also having sizable populations and electrical network systems that were compatible with the UK LV systems (system voltage and frequency; systems having 2-wire, grounded neutral and contiguous ground). The review also assessed which countries would be able to utilise the PEC without modification and which countries were likely to face the same issues in the domestic supply industry as have been experienced in the UK. The findings were detailed in a report by Schneider, “Delivering a Low Cost, High Capacity, Smart Residential Distribution Network: Final report”.

Work package 9:
Work package 9, led by Loughborough University, explored and assessed alternative topologies to the originally proposed AC chopper circuit to evaluate the effectiveness of the different designs that would meet the requirements of the functional specification detailed in WP3. This WP became the key focus of the work following the issues encountered with the prototype design in WP5 & WP6. The aim was to identify topologies that might provide improved performance at reduced footprint and lower cost. This work package also explored different semiconductor technologies, such as GaN, as well as topologies and circuits. The option of GaN devices became viable when it was understood that the voltage rating of the network cabling is limited by the fact that it must be able to withstand the loss of a system neutral. This meant the maximum LV system voltage input that a PEC would need to withstand would be 350Vac rather than 400Vac which brought it into effective range of GaN devices. Tests proved that the proposed alternative design overcame the zero crossing problems that occurred with the AC chopper design in WP5 &6.

A prototype PEC based on the new design and GaN devices has been built and tested. It has proven stable up to 2.5kW. Further work is needed to optimise the design.

Work package 10:
Work package 10, led by Western Power Distribution (WPD), undertook the necessary planning and preparation for site trial implementation. The work intended to identify possible locations with participants that represented the prospective PEC market (based on the proposed design specification from WP3), to liaise with relevant authorities and groups before and during the implementation. The package also identified the data required for evaluation, minimum safety requirements (tests) the PEC had to meet before being accepted for the site trial, possible methods by which to alter the system voltage for the test and other considerations to enable operation during the trials and plans for alternative restoration in the event of a PEC failure.

A review of existing safety standards for power electronic converters highlighted that the requirements would be excessive for the PEC during site trials. A subset of the tests was identified as necessary to demonstrate the PEC's safety before installation in any site trial involving the public. A report "LV Plus: Site Trial Prerequisites" was issued which detailed the necessary in-house electrical, mechanical, abnormal operation and simulated fault test and EMC/EMI tests required

Work was carried to understand the wider requirements for the site trials and a report issued titled LV Plus: Site trial considerations – close out report. The work identified several site trial prerequisites. These included a review of the safety case for the PEC, clear agreement on the individual consortium members' aims and objectives for the trials, suitable design risk assessment to evaluate the failure modes and effects, and evaluation of the effect of the PEC on a proposed location.

Work packages 11:
Work package 11 was allocated for the network trials. However, due to technical issues encountered during the design of the PEC, the site trials were cancelled and no work took place on this package.

Work package 12:
This work package included the data analysis and evaluation of the PEC design and aimed to validate it and the system concepts. It was led by Loughborough University. This package of work was cancelled when the site trials were cancelled.

Work package 13:
This work package was focussed on commercialisation and deployment planning, to understand the cost and size constraints of the PEC and report on commercial viability and overlapped with work packages 7 & 8. This work was led by Schneider and was addressed in detail by work packages 7 and 8. The output of this work package was the exploitation plan which is a mandatory requirement for an Innovate UK funded project. The work included how DNOs might roll out the PEC and how the manufacture and supply change might support this.

Work package 14:
The aim of this work package was to disseminate the knowledge and experienced gained during this project with the wider industry. This was achieved by the presentation of several papers and events (detailed in ‘8 Lessons Learnt for Future Projects’).

Work package 15:
This work package was added during the project and aimed to evaluate the performance of Anvil 3C half bridge modules and packages and was outside of the original LV Plus scope. Anvil had a separate development project in progress to improve the packaging of the devices, in conjunction with a manufacturing centre in Coventry. During the project, it was found that the SiC were not suitable for high frequency switching operations. Anvil then packaged the Cree devices in their package designs. These Anvil packages were put on the board by EMS and tested independently by Converter Technology Ltd. The outcome of WP15 pointed to smaller packages being a possible solution to improved performance.

5 Performance Compared to Original Aims, Objectives and Success Criteria

Objective	Status	Performance
Development of a prototype PEC device at a sufficient Technology Readiness Level (TRL) to enable trials	×	A prototype of the initial 5kW and 20kW AC Chopper design was built and tested but failed to perform. This led to development of alternative topologies, one of which has been developed to the stage of a bench prototype design and was proven stable to 2.5kW. The overall design never reached the stage of a prototype design for installation within a standard meter box. The original aim was not fully achieved however excellent progress was made in all work packages including developing a topology that would make future development and implementation possible.
Increased knowledge and expertise in the use and performance of power electronic converters	✓	This was achieved by the consortium members and information shared via a number reports including: - PEC functional and protection requirements - Statistical studies into the thermal performance of certain devices and topologies - PEC use within Smart Grid applications and the standards that may apply - Performance of different topologies to meet the design specification - Potential future applications and market opportunities for the PEC - Minimum tests to demonstrate electrical safety performance prior to site installation (in this case site trials) Work packages 5, 6, 9 and 15 further developed the understanding of the performance of the new Anvil semiconductor packages in different applications and structures. Importance of the packaging has been more fully understood as a result and proven to be key to the development of a viable solution.

Success Criteria	Status	Performance
Develop a performance specification for the system	✓	The project developed a high level electrical and mechanical performance specification for the PEC. The electrical protection requirements for the PEC were also defined including the protection coordination requirements with downstream consumers.
Carry out R&D of different control and protection strategies to meet regulatory/H&S requirements.	✓	Research was carried out to understand the necessary performance of a PEC to coordinate and integrate with potential downstream consumers. This work led directly to the development of the PEC specification and defined the requirements for any test locations i.e. what sort of equipment (for instance MCBs) and its rating would be necessary to ensure the PEC would provide adequate protection to the consumer from faults. Work also identified necessary regulatory and safety requirements that the PEC would need to comply with before it could be deployed in consumers' properties.
Develop and build a number of new 3C SiC MOSFETs	✓	The project undertook extensive research and development into different system topologies and control algorithms. This was driven partly by the failure of early designs to perform and has resulted in an innovative solution for which the developers are registering a patent. The work demonstrated that the semiconductor packaging is critical and that the most suitable packaging arrangements are only available for GaN devices. The work suggests that the design concept would be independent of the semiconductor technology provided they could be packaged in a similar manner to GaN.

Success Criteria	Status	Performance
Design, build and test a few different prototype PECs	✓	At least three different prototype PECs were built and tested. The initial AC chopper designs (5kW and 20kW) failed. However, promising results have been obtained with an alternative topology and switching control sequence (initial results show stable operation up to 2.5kW). The designs did not progress to the point of allowing integration into a standard meter box as originally intended.
Identify, design and build a test network for the PEC system trials	✗	The site trials did not take place due to challenges faced with the design of the PEC. Work however did take place to define the necessary trial site criteria. Initial work was also carried out to develop methods to modify the network voltage in a small section of a network and to mitigate against a failure of PEC whilst in service to reduce any customer lost time.
Validate the trial data	✗	The site trials did not take place due to problems experienced in the design of a stable PEC. Preliminary work was carried out to define the data required and the most effective means for the data capture.
Devise a road map for future functionality and commercial development.	✓	Work packages 7 and 8 identified possible future functionality for the PEC and associated market opportunities. This included improving the bidirectional performance to cater for imbedded renewable generation and adaptive charging control for electric vehicles. Work was carried out to rank countries' potential as future users of PEC technology and to evaluate the possible size of the market in each of these cases. This work identified that countries with LV electrical network designs similar to the UK, with high car to people ratios and good GDP represent the best opportunities for initial market penetration.

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

There were two formal project change requests made during the project. The first was raised by WPD to change the funding allocated to the project. The second was raised to change from Aston University to Loughborough University and to extend the programme by three months to enable the project to assess a new circuit developed in Work Package 9 due to the problems encountered in the prototype design.

The effected work packages were:

- WP6 Prototype product design – work stopped as focus was moved to WP9,
- WP11 Network trials, WP 12 Data analysis and WP14 Knowledge dissemination were cancelled due to delays in prototype development.

7 Project Costs

Activity	Budget	Actual
Total Project Costs	£159500	£46001

The project costs are lower than the budget as the scope of the project was significantly reduced.

8 Lessons Learnt for Future Projects

The key learning points can be summarised as follows:

1. Initial project scope did not include for any in-house controlled tests and aimed to go straight from design development to site trials. A future project should provide this important stage to validate the design in a controlled environment before considering implementation in consumers' properties.
2. More thorough understanding of the network constraints and requirements earlier on may have resulted in the move to GaN devices sooner. The option of GaN devices became viable when it was understood that the voltage rating of the network cabling is limited by the fact that it must be able to withstand the loss of a system neutral. This meant the maximum LV system voltage input that a PEC would need to withstand would be 350Vac rather than 400Vac which brought it into effective range of GaN devices.
3. The semiconductor packaging is a critical factor and the smaller the package the more effectively it can be used in the PEC design. GaN devices are presently supplied in smaller packages compared with Si or SiC devices.
4. Earlier attempts to maximise the benefits of higher switching frequencies in the design may have led to a viable prototype earlier in the project and a more acceptable cost.
5. Use of higher frequency switching would have reduced the EMC/EMI mitigation measures.
6. The availability of semiconductors (GaN or SiC) in the future may be limiting factor in mass production because other industries such as the automotive sector are presently purchasing large volumes for EV development. This means that chip manufacturers will only have limited supplies available for low volume customers in the future.

9 The Outcomes of the Project

The overall outcome of the project is the development of a GaN based prototype that has demonstrated stable operation at rated voltage up to 2.5kW. It is the view of the project partners that this project has improved the TRL from 2 to 4 because of this project.

The following specific outcomes were achieved by the different work packages:

Work Package 2 - Internal project dissemination and information sharing.
A workshop explored the potential future functionality requirements for the PEC based on possible future market needs such as embedded generation and electric vehicle charging.

Work Package 3 – Technical specification and smart grid requirements

Based on outcomes of WP2 and good practice, a detailed functional requirements specification was developed for the PEC.

The PEC functional specification detailed the intended minimum, maximum and continuous power ratings and the efficiency.

It concluded that the PEC functionality that would complement and support Smart Grid Applications were categorised into three main areas:
- Power quality improvements features
- Protection and reliability features
- Flexibility and manageability features

Work Package 4 – PEC protection requirements

The PEC protection requirements were detailed in the protection specification. The fundamental principles for the protection strategy were defined as:
1. PEC transient overload condition which would allow for loads having high inrush currents.
2. PEC overload condition where the consumer is drawing excess current, but the output voltage remains greater than 188V, in which case the PEC itself would trip.
3. A short circuit condition, where the voltage drops to less than 188V for a time that is greater than would be required to cover inrush. In this instance the PEC will switch to mode that provides fault current to enable the consumer’s MCB to trip.

Work packages 5 & 6: Design and build PEC prototype

The initial 5kW and larger 20kW prototypes using the Cree devices encountered serious problems due to fundamental design issues. The conclusion was that this design was not suitably robust and did not exploit the benefits that high frequency switching could deliver for SiC devices. The physically large components also prevented the mechanical design fitting into a standard meter box as intended.

The Cree semiconductor devices used in the prototype were very expensive resulting in a cost per unit in the order of £3500 per PEC. This was an order of magnitude higher than the original cost boundary identified as making PEC a viable alternative to network reinforcement.

Work packages 7: Smart Grid, power management, EV, DG & energy storage markets

Schneider Electric expect that over the longer term (towards 2050) the trends relating to equipment requirements and take up will become more stable. In response to the Future Energy Scenarios (FES) approach Schneider envisaged only three scenarios – Stalemate Street, Likelihood Lane and Electric Highway. Based on these three scenarios, a Political, Economic, Socio-cultural and Technological (PEST) analysis concluded the following:

- Stalemate street scenario would result in slower PEC take up and that investment would largely be driven by the DNO/DSO and would require the least functionality.
- Likelihood lane scenario would make use of the built-in flexibility to upgrade in a changing marking. It envisaged greater market take up and was likely to be the device of choice (fitted in a meter box) for new builds.
- Electric highway scenarios would require the most flexibility for bidirectional energy flow and even DC distribution. The PEC would need to cater for off grid capability within homes, for example, batteries and PV. The system would integrate with the customer's consumer unit.

PEC functions were of most benefit to either the Distribution or Local Market stakeholders. These stakeholders would benefit from output voltage control, fault current limiting, smart metering and improve power factor control. The PEC functions of most benefit to the consumer were found to be output voltage regulation and smart metering.

Apart from dynamic power factor control, the Distribution and Local Market functionality could be achieved with the base model. The base PEC model meets the most pressing functionality for consumers.

Work package 8: Future products

Schneider concluded that, within the UK, the current PEC functionality is best suited to medium energy use domestic consumers.

Schneider's review of the requirements for European and Global markets focused on countries that had potential growth in smart grid technologies and electric vehicles whilst also having sizable populations and electrical network systems that were compatible with the UK LV systems. The review also assessed which countries would be able to utilise the PEC without modification and identified nine countries; five within Western Europe and the remainder being in the Asia- Pacific region.

Work package 9: Alternative topologies

Assessment of alternative designs resulted in an innovative design using the alternative semiconductor GaN devices. A 2.5kW prototype was successfully developed delivering the following performance.

Parameter	Result
Stable power output	2.5kW for a single module
Switching frequency	250kHz (compared with 30kHz for earlier prototype)
Input voltage (single phase)	350V (maximum voltage that would ensure that network supply cable can still withstand a loss of the neutral)
Output voltage (single phase)	230V
Efficiency	98%
Estimated cost to build GaN prototype PEC	~£2000 – component and configuration cost for low volume.

Work package 10: Site trial planning

The work package identified several criteria that would influence site trial selection. These included size of the trial, housing stock, data requirements, supply restoration options and type of network (private/public).

A minimum set of tests to demonstrate the safety of the PEC prototype were defined based on existing international standards.

The evaluation of data requirements highlighted that, in planning trials, the following would need to be considered:

- remote data download vs. manual data download
- high speed recording vs. long term trending (with exception reporting)
- on board data capture vs. independent verification
- familiarity of trial's partner personnel with proposed data logging equipment

Work Package 15: Evaluation of Anvil semiconductor packages

The evaluation of the Anvil packages found that the standard SiC modules were large compared with the GaN devices and not suitable for switching at higher frequencies. Anvil Semiconductor's "flat pack" design resulted in much smaller modules which performed better than the larger modules.

10 Data Access Details

Due to the cancellation of site trials there is no trial data available. Several reports and documents have been produced during the project. These are given below by work package:

WP3:

Aston University, "Technical Specification - Power Electronic Converter (PEC) Specifications"

Aston University, "Power Electronic Converter (PEC) – Smart Grid Functions"

Aston University, "PEC Impact on LV network"

WP4:

Aston University, "PEC protection strategy"

Aston University, "Technical Specification - Power Electronic Converter (PEC) Test – Protection Functionality"

WP7 & WP8

Schneider Electric, "Delivering a Low Cost, High Capacity, Smart Residential Distribution Network: Final report"

WP10

Uniper Technologies Ltd, "LV Plus: Site Trial Prerequisites"

Uniper Technologies Ltd, "LV Plus: Site trial considerations – close out report"

WP14

Consortium, "Thermal Aspects of a Low-Cost Power Electronic Converter for High Capacity, Smart Residential Distribution Networks," was presented at the 2016 IET 8th International Conference on Power Electronics, Machines and Drives (PEMD)

WP15

Converter Technology, "High Voltage Buck Converter Simulations"

11 Foreground IPR

No foreground IPR was developed as a result of the NIA funding.

12 Planned Implementation

The project has demonstrated that the power electronic converter technology is not suitably developed to enable site implementation at this stage. Further work is required for another 3 or 4 years in the development of the power electronics to reduce both the physical size and cost of the PEC before even a site trial can be attempted.

13 Contact

Further details on replicating the project can be made available from the following points of contact:

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Glossary

Abbreviation	Term
DNO	Distribution Network Operator
DSO	Distribution System Operator
EMC	Electro-magnetic Compliance
EMI	Electro-magnetic Interference
EMS	Exception EMS
EV	Electric Vehicles
FES	Future Energy Scenarios
FMEA	Failure Modes and Effects Assessment
GaN	Gallium Nitride
DG	Distributed Generation
IEEE	Institute of Electrical and Electronics Engineers
IET	Institution of Engineering and Technology
MCB	Miniature Circuit Breaker
OFGEM	Office of Gas and Electricity Markets
PEC	Power Electronic Converter
PEMD	Power Electronics, Machines and Drives Conference
PEST	Political, Economic, Socio-cultural and Technological
PFC	Power Factor Control
SiC	Silicon Carbide
TDCV	Typical Domestic Consumption Values
THD	Total Harmonic Distortion
TPS	Total Power Systems
TRL	Technology Readiness Level
TSB	Technology Strategy Board
WPD	Western Power Distribution
WP	Work Package
UKPN	UK Power Networks