FLEXIBLE PLUG AND PLAY LOW CARBON NETWORKS ENABLING THE INTEGRATION OF RENEWABLE ENERGY

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Abstract-- UK Power Networks has been awarded funding under Ofgem's Low Carbon Networks Fund scheme, to develop the local distribution network using smart grid technologies. The 'Flexible Plug and Play Low Carbon Networks' (FPP) project aims to facilitate faster and cheaper connection of renewable generation onto the distribution network, by using innovative technical and commercial solutions. The FPP project is a £10 million project, which has started in January 2012 and will be concluded in December 2014.

INTRODUCTION

Renewable energy is at the heart of the UK Low Carbon Transition Plan (LCTP) [1]. In the Renewable Energy Strategy [2], the Department of Energy and Climate Change (DECC) sets an ambitious target for 30% of the UK's electricity to be generated from renewable energy sources by 2020 and up to 40% by 2030. However, in their Renewable Energy Review of May 2011 [3] (considering both 2020 and 2030 scenarios) the Committee on Climate Change (CCC) recommended (inter alia) that 'ambition for offshore wind to 2020 should not be increased unless there is clear evidence of cost reduction' and 'if renewable energy targets for 2020 can be made in other ways, a moderation of offshore wind ambition for 2020 would reduce the costs of decarbonisation'. Recognising the need for an affordable low carbon transition, these statements from CCC suggest that a higher contribution from onshore wind generation and other renewable forms of generation to both the 2020 and 2030 targets may be necessary. Given the typical scale of developments, most renewable onshore generation (in England and Wales) will connect to distribution networks.

The problem

UK Power Networks' Eastern Power Networks (EPN) distribution network serves an area of approx. 30km diameter (700 km2) between Peterborough and Cambridge in the east of England which is particularly well suited to renewable generation.

Over recent years UK Power Networks has experienced increased activity in renewable generation development in this area, and a rapid rise in connection applications, with 100 MW of wind generation already connected and around 200 MW at the planning stage. The connection of these anticipated levels of wind generation is expected to require significant network reinforcement to mitigate network thermal and voltage constraints and reverse power flow issues.

Long-Term Development Statements (LTDS), which are produced by all Distribution Network Operators (DNOs) in GB, provide generation developers with some visibility of available network capacity. However, where multiple developments are under consideration, an LTDS cannot provide a reliable indication of the many potential permutations of generation which may eventually be connected, or in what order, or therefore at what point in time substantial reinforcement would be required. This leaves generation developers in the unsatisfactory position of being unable to reliably predict network connection costs or, therefore, the commercial viability of their projects.

The piecemeal approach to network investment arising from generation connection leads to suboptimal solutions giving rise to higher overall network reinforcement and connection costs. In addition, these higher costs and/or the uncertainty of future connection costs can make the financial risk of development of generation unattractive to new developers. This poses a significant risk to the success of the Renewable Energy Strategy and ultimately the LCTP. For the above reasons, the area between Peterborough and Cambridge serves as the ideal test bed for the FPP project.

The proposed solution

The FPP project will trial innovative technical and commercial solutions that allow DNOs to move from a passive 'fit and forget' to a more active 'fit and flex' approach.

The latest developments in open standards and internet protocol (IP) communications is enabling higher speed peer-to-peer communications, simplified system design and commissioning, reduced wiring and bespoke configuration of interfaces, and easier integration and interoperation of equipment from different vendors. The IEC 61850 standard for substation automation promises to enable this integration and interoperability. This will facilitate the widespread adoption of smart devices and applications as required to maximise the contribution from renewable generation. Building a technical platform based on IEC 61850 and IP communications will enable DNOs to more easily and flexibly deploy new technologies and therefore explore a variety of alternative connection solutions for new renewable generators. The FPP project will provide the first opportunity for UK Power Networks to deploy IEC 61850, which will be implemented in addition to the existing suite of open standards protocols utilised in operational telecoms.

Recognising the need to reduce uncertainty regarding connection costs, the FPP project will explore the innovative commercial arrangements that will enable an Active Network Management (ANM) approach.

This will involve establishing contractual arrangements that define access to the network capacity available in real-time for more than one renewable generator. These commercial arrangements will form the basis for considering new technical connection solutions and also the grouping of generators at the planning stage.
The technical and commercial innovation will inform the development of a strategic investment model that will aim to optimise network investment in DG dominated areas.
Underlying the FPP project trials is a proactive and robust stakeholder engagement approach, which will ensure that at every stage of the project key stakeholders such as local authorities and renewable generation developers will be able to contribute to and learn from the FPP project.

The partners

The FPP project will bring together a rich consortium of partners (Fig. 1) to demonstrate how, through the innovative integration of technological and commercial solutions, the cost-effective connection of renewable generation to a distribution network can be achieved.

Fig. 1. FPP project partners

The above partners have been chosen for their breadth of experience, expertise and innovation culture.

DESCRIPTION OF THE FPP PROJECT

The FPP project will use an innovative approach to integrating technology in order to address the problems that were outlined in section I.B above, which include:

Thermal constraints - two 33 kV OH line circuits are the main arteries that transfer power from the wind farms in the central part of the FPP project area. The two circuits are at full capacity, leaving limited headroom to connect additional generation. New renewable generators connecting to this network will be constrained due to the presence of thermal constraints during times of low demand and high generation output. Dynamic line rating has the potential to allow relaxations of existing constraints and obviate the need for prescribed seasonal limits to export to the distribution network.

Reverse power flows - wind generation capacity is further limited by the directional over current protection deployed at a Grid substation within the trial area. The protection settings are a legacy of traditional distribution network operation where power was expected to flow from higher to lower voltages; previously, if current was detected flowing in the reverse direction it was taken to be an indication of a fault. A further constraint is that transformer tap changing relays in the FPP trial area may not support reverse power flow. Modern adaptive protection should alleviate problems due to reverse power flows.

Voltage constraints - It is uncommon for the proposed levels of renewable generation to be connected to an area the size of the FPP trial project area. The operation of the renewable generation is expected to raise voltage levels on the 33 kV network. Modification to the operation of transformer tap changers during times of high generation output and/or the management of generator real and/or reactive power will enable the connection of higher levels of generation while maintaining network voltages within acceptable limits.

Flexible network configurations - Interconnected 33 kV networks give rise to power flows towards the lowest source impedance, which can result in thermal overloads and the other problems listed above at certain pinch points, whilst other circuits with spare capacity remain underutilised. This is particularly evident during network outages. The standard switches currently deployed in the trial area are not designed for frequent operation; replacing these with new 'frequent use' switches not currently deployed in the UK, will enable more flexible network configurations to reduce or remove network constraints. Similarly, on interconnected circuits, active management of power flows using a quadrature-booster will maximise overall network capacity.

Generator control mechanisms - UK Power Networks currently adopts a limited form of active control over generators whereby electro-mechanical relays provide control signals to constrain generator output during unplanned outages. As this system is relay driven, it is a binary action (on or off, or to a number of preset seasonal power export levels) and does not allow the generation export to track to the real-time export capacity available on the network. A more sophisticated electronic based form of ANM will provide greater refinement in the control of both active and reactive power of generator export and enable a closer match to available network capacity.

Interoperability of new controllable devices - In order to fully co-ordinate and leverage the benefits of smart devices and applications, challenges associated with interoperability must be addressed. The implementation of an IEC 61850 based communications system over an IP platform will enable a wide range of vendor products to be trialled and tailored to resolve specific network constraints and demonstrate interoperability.

Commercial arrangements - If generators are to connect to the distribution network and be actively managed (i.e. have their output regulated to meet distribution network constraints) then new commercial arrangements and connection agreements are required. The order in which generators will be allowed to access network capacity available in real-time must be defined. Estimates of anticipated energy volumes exported will require to be provided to prospective developers to allow an assessment of the economics of a smart connection option. In the FPP trial area, there are a number of interactive generator applications; existing practice fails to recognise the potential benefits of considering groups of generators. Considering each generator individually can result in piecemeal and sub-optimal network investment. A commercial framework which supports a holistic development strategy while providing a mechanism that fairly apportionments costs between developers would be a significant advancement on existing connection charge assessment procedures.

Technical innovation - while each of the solutions briefly outlined above would be innovative in their own right, the goal of FPP is to apply a holistic, rather than a piecemeal approach to resolving network constraints to distributed generation and, at the same time, create a commercial framework which will benefit existing and future consumers through more efficient network investment while reducing uncertainty for financial stakeholders in distributed generation development. It is this holistic integration of technologies under an equally holistic commercial framework, using a large-scale test bed of existing and pending generation, which characterises and differentiates FPP as a uniquely innovative project. FPP will enable quicker, more economical and larger numbers of renewable generation connections to distribution networks.

<u>Key stages</u>

The FPP project key stages and elements are as follows:

(1) Design and deployment of an Information and Communications Technology (ICT) platform to facilitate the necessary information exchange and control capability to implement solutions to address the network problems described above. Activities will include:
1.1 Development and deployment of an open standards IP communications platform across the FPP trial area;
1.2 Upgrading of existing Remote Terminal Units (RTUs) to support open standards data communications protocols such as IEC 61850, in addition to the existing protocol set;
1.3 Establishment of a Local Area Network (LAN) in FPP trial substations;
1.4 Deployment of a range of smart devices from various vendors;
1.5 Interoperability testing of smart devices and ANM applications using open standards communications protocols over IP;
1.6 Development of common data models across all smart devices and applications.

(2) Integration of **smart devices** from various vendors to facilitate the management of distribution network constraints to accommodate higher levels of renewable generation. Smart devices include:
2.1 Dynamic Line Ratings (DLR) devices and weather stations at known and future thermal constraint locations, in order to explore whether DLR devices provide an increase in ratings at times of peak loading of the network and if this increase in rating coincides with high output from wind farms and other generators;
2.2 Transformer tap changer control relays at grid and primary substations, in order to examine the scope for introducing greater intelligence into automatic voltage control system to take generator output into account and to prevent voltages from breaching limits;
2.3 Frequent use switches at normally open points, in order to determine the benefits of switches that are designed to operate frequently to reconfigure the network and provide greater flexibility than is possible with fixed 'normally open points' (NOP);
2.4 Generator controllers at new and existing generators. Interface to native generator control systems to explore the potential for monitoring and/or controlling real and reactive power and coordinating this control capability with other smart devices using smart applications;
2.5 A quadrature-booster to be installed within the FPP trial area to overcome an existing constraint due to sub-optimal load sharing.

(3) Integration of **smart applications** such as ANM to monitor real-time network parameters and coordinate and control the operation of multiple smart devices and real and reactive power of multiple generators in order to maintain power flows within thermal constraint at multiple locations and ensure voltage profiles remain within limits.
The application of real-time ratings will involve determining the dynamic ratings of all circuit sections on the network based on weather measurements and a thermal model of the power system. Estimates will be validated by DLR devices, proving the accuracy and validity of estimates and potentially therefore reducing the instrumentation required to achieve DLR.

(4) Development and implementation of **smart commercial arrangements** that are informed by key stakeholder requirements, and identified through a robust and transparent stakeholder engagement process.

(5) Technical and commercial learning will be captured and disseminated throughout the project.

This will be fed into the development of a **Strategic Investment Model** that will identify the triggers for network reinforcement based on what can be technically and commercially achieved using the latest advances in smart grid technology. This project will incorporate and build upon (but not duplicate) learning from other relevant projects being undertaken by other DNOs that are currently underway, representing a significant learning opportunity for all UK DNOs.

FPP PROJECT BENEFITS

Enables economically viable connection of renewable generation

The FPP project will demonstrate the cost-effectiveness of the proposed technical solutions and commercial frameworks through trials and when compared with the traditional approach.

Facilitates the deployment of renewable generation

Learning from the FPP project trials will inform how the deployment of smart devices and applications, and the accompanying ICT, can reduce or defer the need for new distribution network capacity to facilitate the deployment of renewable generation. This aligns with the goals of the Renewable Energy Strategy, which requires significantly more renewable generation to connect to UK distribution networks in short timescales.

CO2 Emissions reduction

The FPP project will result in emissions savings of 242,000 tonnes of CO_2 by enabling greater amounts of renewable generation to connect to distribution networks, more quickly than under a business as usual scenario, and in a cost effective manner. If the methods trialled in the FPP project are subsequently rolled out across the UK, this will result in emissions savings of 4.8 million tonnes of CO_2.

Generates new knowledge and skills

The FPP project will be one of the first in GB to embrace open standards, in particular the extensive use of IEC 61850 and the establishment of IP connectivity both within and between substations. Trials of this approach will generate knowledge and skills in UK Power Networks and their partners. Further development of this knowledge and skills base is essential to ensuring low carbon networks are a practical reality across GB. This is a fundamental objective of FPP which is supported by a comprehensive learning dissemination strategy.

Fosters competition and innovation

The FPP method promises to reduce dependence on a limited portfolio of technology vendors and, in so doing, foster competition and innovation. The flexibility afforded by the FPP methodology means that if such an approach was widely adopted, vendors would have to ensure interoperability to enable the real benefits of coordinated network planning and operation to be realised.

Potential for replication

The FPP method will be generic and hence applicable to all GB distribution networks, irrespective of the fact that the smart devices and applications required in different areas may vary.

CONCLUSION

The Flexible Plug and Play Low Carbon Networks (FPP) project has brought together a rich consortium of partners to address one of the key challenges faced by Distribution Network Operators (DNOs) in enabling the development of a low carbon energy sector. The FPP project will demonstrate how, through the innovative integration of technological and commercial solutions, the cost-effective connection of renewable generation to a distribution network can be achieved.

The FPP technical innovation focuses on the development of a vendor agnostic open standards platform to enable end-to-end communication between distributed smart network technologies and generation. FPP will implement active network management for decentralised monitoring, control and overall operational management of both network and generation. Commercial innovation will be delivered in the form of new contracts to provide flexibility and choice to generation customers. FPP will address the need for a more responsible, cost efficient and flexible approach to generation customer connections.

The knowledge and learning generated from trialing the different FPP project methods will be used to develop a Strategic Investment Model, which will allow DNOs to quantify, for different demand and generation scenarios, the integrated value and benefits of different smart technologies, smart commercial arrangements and smart applications. This model will also determine from both an economic and carbon perspective whether it is better to reinforce the network or use smart alternatives.

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