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THE COST OF ACTIVE NETWORK MANAGEMENT SCHEMES AT DISTRIBUTION LEVEL

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Summary

The growth of wind generation in distribution networks is leading to the development of Active Network Management (ANM) strategies. ANM systems aim to increase the capacity of renewable and distributed generation (DG) that can connect to the network. In addition to DG, ANM schemes can also include storage devices and Demand Side Management (DSM) strategies.

Currently ANM schemes are mainly part of network research and development programmes, funded through network innovation schemes. In future, ANM schemes will need to cover the costs of establishing such a scheme through payments from the network owners and the users of the network.

This paper discusses the current charging arrangements which account for network upgrades and the access arrangements for wind farms connecting to networks which are close to capacity. The Orkney ANM scheme is used as a case study, where the costs of the implemented ANM scheme are compared to conventional network upgrades.

In order to run ANM as a 'business as usual' case, there must be a way in which to recover the costs incurred in implementing and operating an ANM scheme on the network. These costs could be recovered through Use of System (UoS) charging, and there is an opportunity for domestic customers participating in an ANM scheme (through Demand Side Management, for example) to further reduce electricity bills by providing ancillary services to the network.

ANM may increase the cost of electricity for domestic customers, however this increase can be considered substantially less than the cost incurred for significant network upgrades.

1 Introduction

Recent reviews, consultations, and developments such as RIIO-T1 [1] by the gas and electricity regulator, Ofgem have placed a strong emphasis on developing innovative solutions in the way in which they manage networks. Active Network Management (ANM) is just one of these innovative solutions. ANM is the use of IT, automation and control to manage grid constraints associated with the integration of distributed generation. ANM can be used to manage energy producing or consuming devices to resolve network constraints on both Transmission and Distribution systems.

As part of ANM schemes, the network owner/operator may be required to invest in additional network management equipment. This may include

- Communications
- Controllers - for individual users of the network – both generator and demand, and at domestic and commercial level
- Additional Operation and Maintenance costs
- Staff – either additional staff, or training existing staff

The additional costs associated with ANM can be compared to the costs associated with upgrading the physical assets on the network i.e. increasing capacity of existing lines, or the addition of new circuits.

This paper discusses the format ANM contracts for wind generators might take in a ‘business as usual’ case, the benefits of utilising ANM schemes to delay the cost of network upgrades, and the mechanisms through which the costs of ANM may be recovered and

2 Access Arrangements and ANM Schemes

Both the UK Government and the Scottish Government have targets [2, 3] to meet in the coming decades with regard to clean energy resources. Delays to network upgrades would result in a large volume of renewable technologies, such as wind generation, prevented from connecting to the network. ANM is one method of facilitating connection of non-firm generation in the interim while waiting for additional network capacity.

The Register of Active Network Management Pilots, Trials, Research, Development and Demonstration Activities was published in 2008 [4] and lists all projects related to ANM systems, from research projects through to full scale deployment. Network issues that can be resolved through the use of ANM include voltage control, power flow management and frequency issues.

The funds for ANM projects typically come through regulator and government funding. The Low Carbon Network Fund (LCNF) [5] was introduced by Ofgem in 2010. The fund provides support to DNOs in order to allow them to test new technology, and trial operational and commercial arrangements. The aim of the LCNF is to improve knowledge and understanding of DNOs and try out new and high risk technologies that will help in the move towards a low carbon economy.

Registered Power Zones [6] are areas of the National Grid network which have specifically designated for research and development purposes. They are used to try and test out new technologies which will aid the connection of DG at distribution level. There are three RPZ in the UK – Skegness and The Fen, Orkney Islands and Marsham primary.

RPZ and the LCNF are of key importance for the development and deployment of smart grid systems.

3 Types of Access Arrangements

In order to increase the level of generation connected to a network, that is close to capacity, networks can offer a ‘non-firm’ connection arrangement where the generator will be asked to reduce output at times when there are constraints on the network e.g. periods of low demand and high generation. There is no compensation given for curtailment of non-firm generation.

The current method of access arrangement for multiple non-firm generators connected to an ANM schemes, in Shetland and Orkney is ‘Last in First Off’ (LIFO) [7, 8]. In this arrangement the newest generator or last to connect will be first to be asked to curtail should the situation arise. This method is simple to implement, transparent and will not have a negative effect on generators previously connected to the network. However, this method may not be the most efficient way to manage the network, both electrically and economically.

Other options for access arrangements are discussed in [9] and [10]. A number of these are listed below

- Pro-rata: All generators are curtailed equally, in either absolute or relative terms
- Shedding Rota: Generators curtailed according to a rota defined by agreement between the System Operator and participants.

- Curtailment Market: Generators are curtailed according to a market system, such as submitted bids into a balancing mechanism.
- Greatest Technical Benefit
- Greatest Carbon Benefit

Access Arrangements can be split into two main groups, Market Arrangements, and Non Market Arrangements. In all cases, the network operator must assess the impact of the arrangements in terms of fairness, transparency, compliance with current grid codes, flexibility, robustness and their ability to ensure a safe, secure and reliable power system. The impact of the access arrangement on generator long term profit must also be considered, as this will influence the ability of the developer to raise funds for the project from a lending institution.

Non-Market arrangements are arrangements which use predetermined rules to curtail non-firm generation connected a network. These rules are decided by the DNO and generators wishing to connect to the network must adhere to these rules. Generators will have no control over the order of curtailment. Non-market arrangements include LIFO, Pro-Rata, rota and technical best. These arrangements are typically the most straight forward to establish on the network and do not require any changes to grid codes etc.

Market arrangements pass some of the control back to generators in terms of their ability to influence the order of curtailment through monetary bids and offers. This could take the form of a curtailment market where participants bid to remain connected, or be curtailed during a period of congestion. Or participants could bid for a location on the curtailment rota. The creation of market arrangements may require a change to grid codes and they may also encourage incumbent generators to enter the curtailment market alongside non-firm wind generators.

4 Operational and Installation costs of ANM

Incentive schemes and research funding has encouraged the deployment of ANM schemes in a number of distribution networks. ANM is considered a significant alternative to network reinforcements, mainly due to the difference in costs between the two.

The Aura-NMS (Autonomous Regional Active Network Management System) [11] is a research consortium consisting of seven universities, two distribution network operators and ABB. The research focuses on investigating real time control algorithms for voltage control, power flow management and restoration. One of the functions of AuRA-NMS is to automatically detect and offer solutions to thermal overloads which can be caused by the unpredictability of renewable distributed generation. AuRA-NMS has developed control techniques which can be applied to any network topology i.e. all techniques developed are flexible.

In the cost-benefit analysis of Aura-NMS [12], a comparison of voltage control and constraint management techniques proposed by AuRA-NMS and the existing techniques used in a passive network is made. DG is added to two nodes on a small 33kV distribution network, and the changes in voltage and constraints noted. A cost is assigned to voltages in terms of the number of tap changes required by transformers. The cost of constraints is priced per MWh. The paper concludes that the value of the ANM increases as the level of DG connected to the network increases.

Further work by the authors in [13], has shown that network investment can be deferred or reduced by deploying an ANM scheme (AuRA-NMS in this case). The network planning method proposed by the authors considers only the reinforcement on circuits. The objective of the model is to minimise the total cost of network investment and curtailment of wind. Two operational conditions (each with different renewable generation outputs) are considered

- Peak load with zero output of renewable generation

- Minimum load with renewable generation at a maximum

The problem is solved iteratively using Benders' decomposition method. The curtailment of DG output is optimised when the security constraint, N-1 contingency, is violated, and loss of curtailment calculated based on the output duration curve (obtained from historical data on wind speed and the power curve).

The results of the simulation have shown that by installing AuRA-NMS, the network reinforcements of the network in question can be reduced from four circuits to two. The cost of the ANM scheme, plus the two circuits is at a lower cost than the construction of four circuits based on an electricity price of £50/MWh and the cost of ANM scheme being £700k. A sensitivity analysis was carried out to assess the impact of changing costs of electricity and ANM schemes and it was found that the cost of the ANM scheme was still the least cost solution.

The authors have assumed that the cost of ANM would be provided by an 'innovation fund' however as ANM schemes become the 'business as usual' case, the funding for installation and running of the ANM will need to be provided by stakeholders involved in the system e.g. generators, demand customers, network owners and operators.

Similar results are demonstrated in [14] where the value of the ANM increases as the volume of DG connection to the system increases. A comparison of different ANM schemes highlights the importance of generation curtailment (when used with voltage control) to minimise losses on the network, and reduce investment costs. The exclusion of generation curtailment would result in larger Static Var Compensator (SVC) required for voltage control on the network. To contrast, the exclusion of SVC from the ANM scheme reduces losses and investment costs when compared with the use of both curtailment and SVC. However, this will increase curtailment on the network – which could result in higher operational costs of compensation as part of the contractual arrangement.

5 Connection and System Charging

5.1 Transmission

The purpose of system charging is to allow the transmission owner (National Grid in England and Wales, and Scottish Hydro Electrics Transmission Ltd (SHETL) and Scottish Power Transmission (SPT) in Scotland) or system operator (National Grid) to recover the costs of the service they provide at a reasonable rate of return.

Currently, all users (both generation and demand) who wish to connect to the GB Main Integrated Transmission System (MITS) must pay a Connection Charge, a Transmission Network Use of System (TNUoS) Charge and a Balancing Service Use of System (BSUoS) Charge.

The Connection Charge is related to the costs of assets installed in order for that user to be able to connect to the transmission system. These costs can include: civil costs, engineering costs, land clearance and preparation costs.

The TNUoS Charge covers the cost of installing and maintaining the National Electricity Transmission System (NETS) i.e. the physical connection costs which is not specific to the connection site, which is covered by the connection charge The Maximum Allowed Revenue (MAR) is set by OFGEM during the pricing control review for each transmission network operator (TNO). The recovery of TNUoS revenue is split between generation and demand 27% to 73% respectively.

The BSUoS Charge allows the GB System Operator to recover the costs incurred in balancing the transmission system i.e. ensuring safe and secure supply to end users. National Grid is incentivised by Ofgem, the gas and electricity regulator, to acquire these balancing services in a cost effective manner. The Statement of the Balancing Services Use of System charging methodology can be found within the Use of System Charging Methodology (page 72 onwards) [15].

5.2 Distribution

Similarly to transmission network users, distribution network users must pay Connection charges and Distribution Network Use of System (DNUoS) charges.

Depending the location of size of the connectee, the DNO may have to modify an existing part of the network in order to accommodate the generation connection e.g. reinforcements to the network. In addition to charges for network modifications, charges can include

- Connection application fees
- System/feasibility/fault level studies
- Provision of wayleaves
- Meetings with DNO or site visits
- Administration
- Metering charges

Costs of connection paid in full by the connectee include shallow connection costs, e.g. any additional assets required to connect into the network. Any reinforcement required to the shared distribution network is split between the DNO and the connectee. However, reinforcement costs in excess of £200/kW will be charged to the connectee in full.

The split of costs between connectee and DNO is calculated using Cost Apportionment Facts (CAFs). There are two variations of CAFs calculations, Security CAF and Fault Level CAF. The choice is dependent on the requirement for reinforcement.

The Common Distribution Charging Methodology (CDCM) [16] is a common tariff structure used in a 14 DNO areas to set Use of System tariffs. The aim of CDCM is to encourage DNOs to make the most efficient use of network capacity and to reward network users (both generation and demand) who manage their import/export patterns to avoid an increase in power flows during peak periods

DNUoS is categorised by the voltage level at which generation is connected, and the type of meter which is installed (Half Hourly (HH) or Non Half Hourly (NHH)). DNUoS is charged to Electricity Suppliers by the DNO for using the network to transport electricity – this cost can then be passed through to the customer. Generation is also subject to UoS charging, however these charges are currently negative i.e. the generator is seen as negative demand and receives UoS credits.

Under new CDCM for distribution networks, generators who are connected under a non-firm arrangement have a deemed capacity of 0MW, and therefore this section of the UoS charges will be zero. Non-firm generators are still required to pay for connection charges in order to obtain connection to the network.

6 Case Study – Orkney ANM Scheme

A report produced by KEMA [17] on the Orkney ANM scheme highlights the project successes and problems encountered during the creation of the scheme.

The Orkney ANM project was implemented as an alternative solution to network reinforcements. The reinforcements were in the form of a new subsea cable linking Orkney to mainland GB grid, which would have cost an estimated £30million. Regardless of the construction of the subsea cable, there would still be local constraints on the network which would require some form of constraint management.

The total cost of the ANM scheme is £500k. Project developers remained interested in connecting to ANM scheme regardless of projected curtailment figures.

From inception, the Orkney ANM scheme took 6 years to reach operational stage. This lengthy period was the result of advanced modelling required for generators, extensive testing, and external causes such as planning consent and construction work.

In order to create the real time ANM system, the appropriate protection systems had to be installed, similarly SCADA systems and the controllers and monitors required to operate the ANM system had to be installed on the network.

One of the consultancies involved in the research and development of the Orkney ANM scheme now holds a contract with the network to analyse and monitor the total curtailment of the generators connected to the network, and to validate the estimates made during connection agreements. The same consultancy also provided training packages for the network control room staff.

The one of the key lessons learned from the Orkney ANM Scheme was the importance of communication systems. The communications for each curtail-able site was the responsibility of the generator. While some generators installed a more reliable VHF radio link, there were problems with existing radio links which operated at a lower frequency. When the communication links between generators and network were down, generators were automatically tripped off the system to prevent any network problems. However initial due to unreliability of some communication links, this has led to large levels of unnecessary curtailment for some generators.

In the future, the network could set minimum levels of technology which are required for the ANM schemes in order to avoid unnecessary curtailment.

7 Discussion

The cost of ANM has been demonstrated to be lower than traditional network reinforcements. However the mechanism by which costs are recovered by the network needs to be defined.

As discussed in Section 5, the costs of network reinforcements are recovered through a combination of connection and use of system charging depending on the voltage level of the connection. To date, the cost of ANM schemes has been largely funded through network research and development funds, and schemes such as RPZ and LCNF. As ANM schemes become a ‘business as usual’ model, a mechanism by which the network can recover the costs of installing, operating and maintaining an ANM system must be established. The model shown in **Figure 1** demonstrates the flow of money and services between a number of key stakeholders in an ANM scheme. This is a format developed by Oxford Business School [18] and has been used to show similar transactions for distribution network market structures.

The base case against which all flows are compared is a standard network configuration, without the inclusion of any network management of incentives to encourage renewable energy and most domestic electricity users sourcing power from vertically integrated suppliers and large centralised generators.

In **Figure 1**, the installation of an ANM scheme on the network allows more wind to connect to the network. This reduces the volume of electricity provided by conventional generating methods and therefore reduces the emissions of the distribution network.

The cost of the ANM Kit is paid for by the Wind Farm, which will experience lower connection costs than that of typical connection agreements.

There will be higher DNUoS charges due to an increase in Network Equipment and management, this however, is lower the the costs which would be incurred if Network Reinforcements were taken forward.

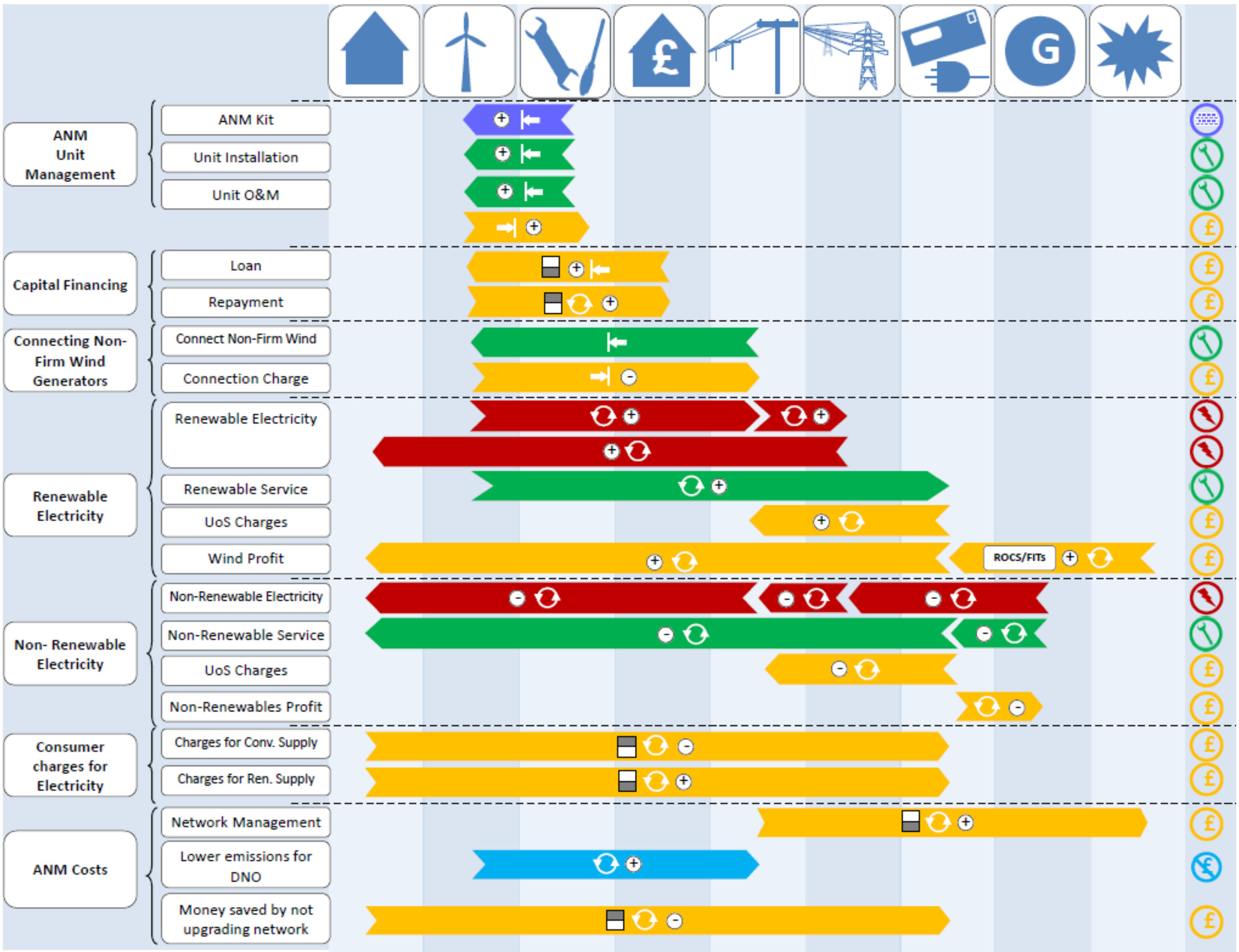

Figure 1: Business model of ANM scheme (Based on models produced by Supergen HiDef Distributed Energy Business Modelling [18])

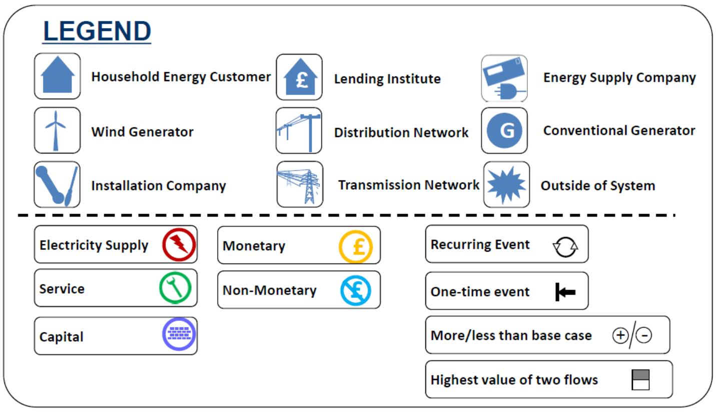

Figure 2: Legend for Business Model in Figure 1.

In addition to the basic recovery of costs for the construction, operation and maintenance of the ANM scheme, there is the option to create ancillary services by incentivising domestic Demand Side

Management (DDSM). The installation of storage devices in the homes of domestic customers is being trialled by Scottish & Southern Electric (SSE) for the Northern Isles New Energy Solutions (NINES) project [8]. As part of this project, SSE are also required to come up with a method of incentivising the uptake of storage devices in the homes of domestic customers and a mechanism through which to distribute the incentive.

8 Conclusion

Changes to connection arrangements for generators connecting to ANM schemes could increase customer bills; however this increase will be a fraction of the cost which would be incurred as a result of network upgrades.

All costs for creating and managing ANM schemes could be recouped through Use of System (UoS) charging by introduction of a market for ancillary services. This market would be simpler than market at transmission level. These charges filter down to consumer tariffs. Customers would be entitled to 'rewards' based on their level of participation in ANM schemes.

DG would participate in a curtailment market where generators bid on a day-ahead basis for access to the network during constraints. All costs are recovered during a settlement period which would see generators pay or be paid through UoS monthly payments.

There is potential for ANM schemes to increase consumer bills, however there will be options available for customers to participate more actively in ANM schemes through the use of demand-side management which can result in rewards for customers, and possible reductions in energy bills.

9 References

[1] Ofgem. (2012, 15th January). *RIIO-T1 (first transmission price control review under the RIIO model)* Available: http://www.ofgem.gov.uk/Networks/Trans/PriceControls/RIIO-T1/Pages/RIIO-T1.aspx

[2] DECC. (2008, 15th January). *Carbon Budgets*. Available: http://www.decc.gov.uk/en/content/cms/emissions/carbon_budgets/carbon_budgets.aspx

[3] Scottish Government. (2009). *Climate Change (Scotland) Act 2009*. Available: http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/climatechangeact

[4] R. A. F. Currie and G. W. Ault, "Register of Active Management Pilots, Trials, Research, Development and Demonstration Activities," 2006.

[5] Ofgem. (2012, 7th September). *Low Carbon Networks Fund*. Available: http://www.ofgem.gov.uk/networks/elecdist/lcnf/pages/lcnf.aspx

[6] Ofgem. (2012, 7th September). *Innovation*. Available: http://www.ofgem.gov.uk/Networks/Techn/NetwrkSupp/Innovat/Pages/Innvtion.aspx

[7] R. A. F. Currie, G. W. Ault, C. E. T. Foote, N. M. McNeill, and A. K. Gooding, "Smarter ways to provide grid connections for renewable generators," in *Power and Energy Society General Meeting, 2010 IEEE*, 2010, pp. 1-6.

[8] Scottish and Southern Energy Power Distribution. (2012, 13th November). *Northern Isles New Energy Solutions (NINES)*. Available: http://www.ssepd.co.uk/News/NINES/

[9] R. A. F. Currie, O'Neill, B., Foote, C., Gooding, A., Ferris,R., Douglas, J. , "Commercial Arrangements to facilitate active network management," in *CIRED 21st International Conference on Electricity Distribution*, Frankfurt, 2011.

[10] ESB National Grid, "Options for Operational Rules to Curtail Wind Generation," CER/04/247, 2004.

[11] E. M. Davidson, M. J. Dolan, G. W. Ault, and S. D. J. McArthur, "AuRA-NMS: An autonomous regional active network management system for EDF energy and SP energy networks," in *Power and Energy Society General Meeting, 2010 IEEE*, 2010, pp. 1-6.

[12] H. Zechun and L. Furong, "Cost-Benefit Analyses of Active Distribution Network Management, Part I: Annual Benefit Analysis," *Smart Grid, IEEE Transactions on,* vol. 3, pp. 1067-1074, 2012.

[13] H. Zechun and L. Furong, "Cost-Benefit Analyses of Active Distribution Network Management, Part II: Investment Reduction Analysis," *Smart Grid, IEEE Transactions on,* vol. 3, pp. 1075-1081, 2012.

[14] D. Papadaskalopoulos, E. Manitsas, P. Mancarella, and G. Strbac, "Optimization of operating and investment costs of active management deployment in distribution networks," in *PowerTech, 2011 IEEE Trondheim*, 2011, pp. 1-8.

[15] National Grid, "The Statement of Use of System Charging Methodology," April 2010.

[16] Ofgem, "Electricity Distribution Structure of Charges: the common distribution charging metholody at lower voltages," Decision Document 20th November 2009.

[17] KEMA, "Smart Grid Strategic Review: The Orkney Islands Active Network Management Scheme," 8th March 2012.

[18] Environmental Change Institute at University of Oxford. (2011, 2011). *Supergen HiDEF Distributed Energy Business Modeling*. Available: http://distributed-energy.ouce.ox.ac.uk/debmvefsplash.php#