Institution: University of Strathclyde

Unit of Assessment: 13

Title of case study: Economic and environmental benefits from adoption of active power network management scheme

1. Summary of the impact (indicative maximum 100 words)

Research at the University of Strathclyde between 2003 and 2008 directly produced the following impacts from 2008 onwards: 10 wind farms (17 MW aggregate capacity) connected to the Orkney power network from 2009 to 2013 with accompanying economic and environmental benefits; Orkney power network reinforcement deferral saving of £30M from 2009 with repeat deployments of Active Network Management (ANM) technology in other UK power networks; spin-out company formed in September 2008 with total revenues to date of £6.1M, equity investment totalling £3.5M and 35 FTE jobs created; provision of new power system options for long term network plans impacting the 2013 investment decisions in distribution network companies; contribution to the emerging Smart Grid business sector in the UK and overseas from 2008.

2. Underpinning research (indicative maximum 500 words)

Context: The research was undertaken in the context of the growth of renewable generation in the UK and the barriers to its connection to the power system, including overcoming network capacity constraints which became the focus for this case study.

The research led by Graham Ault was undertaken in a single core project 'Facilitate Generation Connections on Orkney by Automatic Distribution Network Management' (June 2003-April 2004, Department of Trade and Industry) with Scottish & Southern Energy Power Distribution Ltd (SSEPD). The aim was to define the active power flow management problem, and propose and test solutions taking account of prevailing power network planning and operations standards. Active power flow management involves calculating and executing control actions in power networks to achieve objectives such as integrating renewable energy generation or reducing electrical losses. Ault worked in close collaboration with SSEPD and this became a vital part of the subsequent deployment of a solution and the generation of the impacts described in this case study.

Two further sequential projects from 2006 to 2008 [Grants 6 and 7] refined the methods for design of the active power flow management scheme in terms of control zone definitions (based on identification through analysis of critical power network constraint locations) and trigger threshold calculations (based on assumed ramp rates for energy generation and demand, and communication and control time delays).

Key Findings: The initial research resulted in the core concept for Active Network Management (ANM) with the Orkney power network. The core research contributed an ANM requirements specification (including functional and non-functional elements), algorithms for control (including identification and resolution of multiple power circuit constraints) and a conceptual design (including measurement, communications, control hardware and software) for a deployable ANM system. The project was a significant step towards a deployable ANM solution based on underpinning power system and control research. The research also provided the necessary technical detail to allow discussion of the implementation of ANM concepts within the industry.

Ault and Currie worked with SSEPD personnel to establish the conceptual design for an active power flow management approach based on measurement of circuit power flows and the regulation of wind farm power output to relieve network constraints. This was based on methods to calculate the wind generation constraints and economic feasibility of wind power in such an ANM scheme [1]. The wind generation constraint assessment (later generalised to any type of generation or electricity demand) enables a time series of electrical demand and generation (in half-hourly or higher resolution) to be assessed over a significant timescale (e.g. years) to quantify the number of constraint periods and the total constraint energy volume for one or more generators. The economic impact of loss of generation revenue from energy sales and any

renewable certificates or incentives can then be calculated.

A further core research challenge tackled was a method for calculation of appropriate operating margins for an ANM scheme. This is important as operating margins that are too narrow present power network security risks, whilst margins that are too conservative and wide limit access to the available network capacity for power generators. The research presented a method of calculating multiple operating margins that could be applied within an ANM scheme [2].

The practical implementation of an ANM scheme requires that a power network is organised into different zones of control. The research established the method for identifying these zones of control, with reference to the identification of all possible network constraint locations. This approach was embodied in a patent [3].

Key Researchers at Strathclyde: Graham Ault led the research throughout. He was a Research Fellow in 2003, and progressed to Senior Lecturer (2005), Reader (2008) and Professor (2010) in the Department of Electronic and Electrical Engineering. Robert Currie was Ault's PhD student at the start of the research in 2003, became Research Assistant at Strathclyde (2006) before leaving the University to join Smarter Grid Solutions Ltd (2008) where he is still the Technical Director.

3. References to the research (indicative maximum of six references)
Outputs 1 and 2 best indicate the quality of the underpinning research

[1] Currie, R.A.F., Ault, G.W., McDonald, J.R, 'Methodology for determination of economic connection capacity for renewable generator connections to distribution networks optimised by active power flow management', IEE Proceedings - Generation, Transmission and Distribution, 2006, vol. 153, Issue 4, pp 456 – 462.

[2] Currie, R.A.F., Ault, G.W., Foote, C. and McDonald, J.R., 'Active power-flow management utilising operating margins for the increased connection of distributed generation', IET Generation, Transmission and Distribution, 2007, vol. 1, no. 1, pp. 197-202.
This paper set out the basis for operating margins in the public domain that was taken forward and fully set out in the second patent [ref 4 below].

[3] GB Patent No. GB0901968 'Active Network Management Scheme' (Zones). Filed November 2008, Granted.
This patent defines control zones in an active power flow management scheme to underpin the design of the active network management scheme.

[4] GB Patent No. GB2476396 'Active Network Management Scheme' (Triggers). Filed November 2008, Granted November 2011.
This patent defines the method for calculating operating margins (thresholds) which underpin the control instructions generated to deliver active power flow management.

Other Evidence for quality of research: The research was supported by the following funding

[5] 'Facilitate Generation Connections on Orkney by Automatic Distribution Network Management', June 2003-April 2004, DTI funding award: £116,100 to Scottish Hydro Electric Power Distribution Ltd. (Strathclyde part: £58,000), Project Ref. K/EL/00311/00/00. Grant Holders: J.R. McDonald and G.W. Ault. Researcher: Robert Currie.

[6] 'Orkney Registered Power Zone (RPZ) Research & Development Project', Scottish Hydro Electric Power Distribution Ltd., April 2006 - March 2007, £55,464. Principal Investigator: Graham Ault. Employed Researcher: Robert Currie.

[7] 'Scottish & Southern Energy Research Fellowship', January 2007 – August 2008, £74,731. Principal Investigator: Graham Ault. Employed Researcher: Robert Currie
This project supported the completion of research tasks and supported the transfer of knowledge into the trial ANM deployment for the Orkney power system.

The IP generated in the research and now licensed from the University of Strathclyde to Smarter Grid Solutions Ltd. includes the two granted UK patents, two patents in Europe EPO and US USPTO that have been accepted with grant dates in June and July 2013, respectively, and the

software code for the constraint evaluation tools.

4. Details of the impact (indicative maximum 750 words)

Process from research to impact: The research undertaken at the University of Strathclyde between June 2003 and June 2008 was conducted in close collaboration with Scottish & Southern Energy Power Distribution (SSEPD). As research results generated from 2005 until 2008 started to look promising and the proposed Active Network Management technology looked viable, discussion turned towards implementation in the Orkney network as a technology trial. The main focus of the activity under the two follow-on contracts (April 2006 – June 2008, [Refs 6-7] involved knowledge exchange into SSEPD, into SSEPD's contractors for the trial deployment, and into the patents drafted and submitted in 2008 [Refs 3 and 4]. On the basis of the research, SSEPD took the decision that a viable alternative to network reinforcement (through an additional subsea cable to connect Orkney to the mainland) was available, with considerable cost savings as outlined below.

Types of Impact: The following impacts arose from the collaborative programme of research.

Commercially successful spin out created: As SSEPD explored how to support the deployment of ANM on Orkney and elsewhere, discussions around commercial spin-out from the University of Strathclyde began and quickly developed into a proposal approved by the university and external investors (Scottish & Southern Energy Venture Capital and the Scottish Co-Investment Fund managed by the regional development agency Scottish Enterprise). Smarter Grid Solutions Ltd was incorporated in June 2008 and spun out from the university on an arm's length basis in September 2008. The spin-out process enabled a focus on industry needs to deliver ANM technology on a fully supported commercial basis. Smarter Grid Solutions Ltd. has grown substantially since formation in 2008 with total revenues to the end of March 2013 standing at £6.1M from projects with UK and European power network operators. These revenues are based on the core ANM technology researched and developed at the University of Strathclyde. Smarter Grid Solutions Ltd. employs 35 FTE staff (at May 2013) and supports several companies in the UK and overseas on smart grid investment, trial and roll-out. The company has received equity investment totalling £3.5M to 2013. [Source A supports all claims related to Smarter Grid Solutions.]

New technology adopted: From 2009, SSEPD started connecting additional wind generation to the Orkney power system under the ANM scheme. Until that point the network had effectively been closed to new generation connections due to network thermal capacity constraints and this has been resolved through application of the ANM solution delivered by Smarter Grid Solutions Ltd.

Cost savings to Scottish and Southern Energy: The deployment of ANM technology on the Orkney power network in 2009 has resulted in power network reinforcement deferral savings of £30M from an avoided additional sub-sea power cable from mainland Scotland to Orkney [Source B].

Costs and customer benefits: As highlighted within the UK Power Networks Business Plan [Source F], significant savings have been produced following a trial of the Flexible Plug and Play Network (FPP) which utilised the ANM method resulting in an average saving of 87% covering six wind farms. Economies of scale have reduced the costs of the ANM system and telecommunications platform for the FPP project to about £2 million.

Power generation: The deployment of ANM technology on the Orkney power system has led to the connection of 18 additional wind farm developments with 25.91MW aggregate capacity on the Orkney power network between 2009 and 2013. There are carbon reduction and local, social and economic benefits from the development of these additional renewable generation schemes, and wind farms connected to Orkney gained earlier and cheaper access to the power system through the deployment of ANM technology [Source C].

Changes to investment strategy of UK network operators: The research and subsequent commercial deployment of ANM technology has provided new power system investment options

for the UK distribution network operators and these have fed through into their 8-year investment plans being published in 2013 [Source E and F]. Smarter Grid Solutions Ltd. has been at the forefront of advising UK power companies on ANM technology and this impact on design and investment policy is a direct result of the research. In the UK, the impact of successful deployment of ANM technology on Orkney has given confidence to power companies to invest in further deployments of this technology under innovation funding (i.e. Low Carbon Network Fund) and to include ANM technology in their investment plans for the period 2015-2023 under the RIIO price control mechanism [Source D]. The ANM technology (being promoted by Smarter Grid Solutions Ltd.) has been the focus of industry wide assessment in the Ofgem/DECC Smart Grid Forum Workstream 3 modelling activities in 2012/13, and has been the focus of business planning activities with all 6 of the UK Distribution Network Operator companies (i.e. Scottish & Southern Energy Power Distribution, Scottish Power Energy Networks, Western Power Distribution, UK Power Networks, Northern Power Grid, and Electricity North West).

Wider adoption: By July 2013, Smarter Grid Solutions Ltd. was in advanced stages of discussion relating to feasibility assessment and deployment with clients in the EU, US and Asia Pacific. Smarter Grid Solutions personnel have presented training and knowledge exchange workshops, training session and tutorials for international recipients at trade exhibitions, and workshop events and company seminars in the EU, US and Asia Pacific.

The impacts described above indicate the financial, economic, employment, and design benefits that have resulted from the research into ANM technology at the University of Strathclyde. Furthermore, the success of the technology is now informing long term strategy and investment plans of the UK distribution network operators.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Managing Director (Smarter Grid Solutions Ltd.) and the company financial statements for 2009, 2010, 2011, 2012 and 2013 will support the claim(s) that Smarter Grid Solutions was formed on licensed technology from the University of Strathclyde and that the company has grown to the revenue volume (plus other financial indicators) and staff complement claimed.

B. SSEPD Technology Manager (SSEPD) will support the claim(s) that Orkney power network reinforcement deferral saving due to the ANM implementation was approximately £30M and that this technology and the spin-out company, Smarter Grid Solutions, have contributed substantially to the new smart grid business sector in the UK and are changing the way that networks are planned through business plans for the 2015 Electricity Distribution Price Control Review. Will also confirm the 17MW connected and >20MW planned wind generation connections through ANM on Orkney.

C. Chairman (Hammers Hill Energy, Orkney) will support the claim(s) that wind farms connected to Orkney gained earlier and cheaper access to the power system through the deployment of ANM technology.

D. Future Networks Manager (Western Power Distribution) will support the claim(s) that the ANM technology is being rolled out by other UK power companies and being incorporated into business plans for the period 2015-2023 under the RIIO price control mechanism.

E. Future Networks Manager (Scottish Power Energy Networks) will support the claim(s) that ANM technology based on University of Strathclyde research is impacting the investment planning and network design policies in UK distribution network companies.

F. UK Power Networks, Business Plan 2015 – 2023, Annex 9: Smart Grid Strategy, July 2013: http://library.ukpowernetworks.co.uk/library/en/RIIO/RIIO_ED1_Business_Plan/UKPN_Smart_Grid_Strategy.pdf