Programme Area: Energy Storage and Distribution

Project: Network Capacity

Title: Executive Summary

Abstract:

This Network Capacity project was commissioned to: assess the feasibility of using new technologies to enable the installation of significantly increased levels of renewable energy sources in the UK and provide recommendations identifying possible technology development intervention opportunities derived from the analysis. The technologies considered in the project included: a range of power electronic based conversion systems and active network management techniques, reactive power compensation technologies, multi-terminal HVDC[1] systems, and the feasibility of incorporating multi-terminal HVDC into the existing UK electricity network.

Context:

The Network Capacity research project identified and assessed new technology solutions that could enhance transmission and distribution capacity in the UK. It assessed the feasibility and quantified the benefits of using innovative approaches and novel technologies to provide improved management of power flows and increased capacity, enabling the deployment of low carbon energy sources in the UK. The project was undertaken by the management, engineering and development consultancy Mott MacDonald and completed in 2010.

ETI Executive Summary

Programme: Energy Storage and Distribution

Project Name: Network Capacity

Deliverable: Final study report

Introduction

Within the Energy Storage & Distribution (ESD) programme, the Network Capacity project was commissioned to:

- Assess the feasibility of using new technologies to enable the installation of significantly increased levels of renewable energy sources in the UK by
    a. providing increased transmission & distribution capacity and
    b. providing better control of network power flows
- Provide recommendations to the ETI identifying possible technology development intervention opportunities derived from the analysis above.

The technologies considered in the project included:

- a range of power electronic based conversion systems and active network management techniques (to improve system flexibility, operational management and dynamic control),
- reactive power compensation technologies (for improved voltage control)
- multi-terminal HVDC[1] systems (to improve bulk power transfer capability).
- the feasibility of incorporating multi-terminal HVDC into the existing UK electricity network, and an analysis of the benefits of converting existing AC lines to DC.

This project is unique from other publicly-available studies in that it is focused on the implications of electricity network development requirements on technology development, as opposed to developing specific network design scenarios.

The project has identified and assessed solutions to the key challenges, examined benefits and informed the ongoing strategic development of the ETI's ESD programme.

The project ran from November 2009 until December 2010, and was delivered by a project team comprising:

- Mott MacDonald (as Prime Contractor)

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[1] High Voltage Direct Current

- the University of Strathclyde (contributing expertise in power electronics and other technologies)
- Smarter Grid Solutions Ltd (an SME specialising in active network management technologies)
- the Manitoba HVDC Research Centre (one of the world's foremost centres of expertise in High Voltage Direct Current technologies and applications), and
- TransGrid Solutions Inc (an SME contributing power system services expertise, particularly HVDC and Flexible AC Transmission System technologies and system studies)

At the ESD SAG meeting on 30th September 2010, member representatives confirmed acceptability of all reports delivered.

Project Outcomes

Mott MacDonald has provided a good executive summary of the project in their final report. This report[2] is available on the ETI member portal.

Table of project deliverables: all available on ETI member portal

Deliverable
WP1 Task 1 Report: Power Electronic Technologies - Literature Review
WP1 Task 2 Report: Impact of Active Power Flow Management Solutions
WP1 Task 3 & WP2 Task 2 Report: Model Validation
WP1 Task 3 Report: Transmission System and Integration Studies
WP1 Tasks 4 & 5 Report: Barriers to Development and Environmental & Social Impacts
WP1 Tasks 6 & 7 Report: Technology Options, Benefits and Barriers Workshop and Multi-Criteria Assessment

[2] Work Package 1 Task 8 Final Project Report - Assessment of New Methods of Enhancing the Onshore UK Electricity Transmission & Distribution System to Enable Increased Renewable Energy Connection. Mott MacDonald

Deliverable
WP2 Task 1 Report: Multi-Terminal HVDC Feasibility
WP2 Tasks 2 & 3 Report: Performance Studies and Impact Evaluation of HVDC in Existing Network
WP2 Task 4 Report: Barriers and Supply Chain Issues
WP1 Task 8 Report: Final Summary Report (for both WPs)
Models: Models used for studies
Study Appendices: Individual result plots (running to hundreds of pages)

Key Findings and Insights

This section sets out the ETI strategy manager's observations on the technical findings and insights of the project.

Key Deliverables Arising from the Project

The key deliverables arising from the project are:

- A model of the UK electricity transmission system suitable for steady-state and dynamic analysis. This model was a development of Mott MacDonald's pre-existing steady-state model. It was tested and validated by National Grid as being fit for the purposes of the project and for future analysis of this type.

- Results of literature surveys and engagements with equipment manufacturers that identify the current state-of-the-art and technology development challenges.

- Electrical system modelling (using the UK grid system model developed above), benefits analysis and the assessment of barriers to deployment of identified technologies integrated into the UK electricity system.

- The identification of post project opportunities for technology development intervention and demonstration through structured multi-criteria analysis.

High-level Findings and Observations

- There are a number of important issues in the onshore grid system that is a function of the grid network, rather than the technologies themselves. These must be considered for applications of HVDC, or other power-electronic based technologies. One example is the need for the grid to withstand the loss of an HVDC link with enhanced power transfer capability without exceeding thermal or stability limits elsewhere in the system. This is likely to limit the potential applicability of HVDC onshore in the UK.

- New wide band-gap materials such as silicon carbide (SiC) and gallium nitride have the potential to deliver increased power electronic device voltage ratings, reduced switching losses, and raised operating temperatures. This has the potential for significant impact on the cost and performance of power electronic converters. However, major technology advances would be required to achieve the high voltage, high power modules needed for transmission system application of such devices. The innovations needed for distribution system application are likely to be more achievable.

- The deployment of TCSCs[3] on selected transmission corridors in the UK may improve the grid system's ability to recover to stable operation following selected (unplanned) double circuit outages. These devices have not been deployed in the UK to date, although experience does exist elsewhere.

- In some circumstances, HVDC transmission can provide benefits by enabling long distance power transmission, eliminating reactive power flows from long HVAC cable circuits and enabling asynchronous system connections. However, these are unlikely to be of significant benefit to the onshore UK transmission system in view of its (generally) short transmission distances and heavily interconnected nature.

- The conversion of selected transmission corridors from AC to HVDC may improve the grid system's ability to recover to stable operation following selected (unplanned) double circuit outages.

- Multi-terminal HVDC (necessary for embedding DC interconnectors in a meshed system) is feasible with both LCC[4] and VSC[5] technologies. Presently the use of LCC technology in a multi-terminal HVDC system configuration is limited to three terminals; this is due to technical difficulties such as increased control system complexity and DC current balancing between the converters. In principle, a multi-terminal VSC-HVDC transmission system can be extended to any number of terminals without significantly increasing the converter power system complexity. However, a highly co-ordinated control system is required, and robust DC circuit breakers will be required, to improve the possibility of system recovery from DC faults or loss of converters.

- For a given transmission tower ('pylon') size significantly more power can be transmitted on a DC circuit than on an AC circuit (typically two to three times). However, to date there has been only one line in the world where conversion has actually taken place.

- There appears to be no benefit case for converting individual transmission lines in the UK Grid to HVDC to gain additional transmission capacity since:

    - Conversion to HVDC will, at the very least, entail the replacement of all of the insulators on the line. This conversion would be expensive and would involve

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[3] Thyristor Controlled Series Capacitors

[4] Line Commutated Converter

[5] Voltage Source Converter

taking the line out of service for a considerable time, which may be operationally unacceptable in practice.
    - The Grid would be unable to cope with the loss of the enhanced capacity transmission line without the need for additional capacity enhancements in adjacent circuits and the possible need to implement associated special protection schemes.
    - The converted line is unlikely to offer any other (non-capacity related) benefits to the system that cannot be gained by other means, such as the application of conventional compensation plant.

Specific Technology Opportunities

A total of 26 specific technology opportunity areas were identified by the project consortium as worth further examination by the ETI. Selected examples of these are reproduced below to illustrate the range of topics identified and potential opportunity areas for ETI.

- Power electronic devices & materials
    - Increase the present current handling capability of IGBTs beyond 1500 A. This requires better packaging techniques such as the development of improved, multi-wafer packaging. Advances in this technology need to be targeted towards the power systems industry instead of focussing towards smaller, lower power electronic applications.
    - Improve the present voltage operating limits for IGBTs and thyristors of 6.5 kV and 8 kV respectively. This would potentially reduce the need to stack devices in series to achieve higher voltage operation thereby reducing costs.
    - Improve the ability of power electronics to deal with transient overloads.
    - Collect the appropriate statistical data needed to allow a substantiated reliability assessment of voltage source converters (VSC) to be carried out.

- Power electronic systems
    - Assess the potential opportunities for series compensation to be applied on the interconnected 132 kV network in England and Wales, and bring forward associated technology developments.

- HVDC circuit breakers and protection
    - Development and demonstration of high voltage & high power DC circuit breakers capable of interrupting DC line faults.
    - Development and demonstration of protection systems that can identify and isolate faulted sections of multi-terminal HVDC networks. These protection schemes must be integrated with hardware that can achieve rapid re-energisation of the DC network.

- Active Network Management & Smart Systems

- Pilot projects for providing experience and confidence in the adoption of new power flow management techniques.
- The development and demonstration of dynamic thermal rating solutions integrated with current network technologies (e.g. SCADA[6], substation relays).
- The development and demonstration of new voltage management techniques driven by improvements in technologies for measurement, computation and communications.
- The demonstration of new Demand Side Management (DSM) techniques, including:
  - appliances and industrial processes allowing a degree of flexibility in energy consumption,
  - the roll-out of smart meters and the installation of suitably controllable loads,
  - the increased use of electrical heating and cooling, which offers scope for exploiting thermal inertias and energy storage, and
  - developments in information and communication technologies to make the implementation of the necessary control systems cheaper and less complex.
- The development and demonstration of protection and control systems for distributed generation plant, integrated into combined interface units that provide cost-effective control, without sacrificing the safety provided by protection.
- The development and implementation of network simulation and analysis tools to allow DNOs to manage generator-network interactions and a range of system issues like constraints, outage co-ordination, stability and security, and system recovery and restoration.

Verification of Data

Throughout the delivery phase of the project the Energy Storage & Distribution SAG have been involved in the assessment of project deliverables and have provided very helpful and insightful contributions. These have been discussed with the project consortium on an ongoing basis and have been incorporated in deliverable updates where appropriate.

The UK grid model developed by Mott MacDonald that was used to inform some of their project recommendations was reviewed and validated by a small sub-group containing E.ON, EDF and National Grid. Importantly National Grid provided written confirmation that the model was representative of the UK grid system and fit for the purpose required.

[6] Supervisory Control and Data Acquisition systems