DS3:
Voltage Control Workstream (2013–2015)

CONTEXT

The system voltage is determined by the balance of reactive power production and absorption. Conventional generators have traditionally been a primary source of reactive power, which compensates for the reactive power produced and absorbed by consumers and by the lines and cables on the network itself. Reactive power, unlike active power, is predominately a local phenomenon, i.e. reactive power cannot be transmitted over significant distances.

The management of voltage requires a co-ordinated approach for reactive power control throughout the whole system, both transmission and distribution in Northern Ireland and Ireland, as deficiencies in a local area at a certain point can have an inordinate impact on other voltages, potentially leading to voltage collapse.

The management of system voltage needs to evolve due to the changing nature of the portfolio of plant connected to the power system. Key changes relate to the type of generation connecting to and being decommissioned from the system, the location of said generation and the reactive power capability of connected plant. The report published by the TSOs in July 2011[1] (hereafter referred to as the DS3 Report) outlined the current issues relating to voltage control and the likely challenges that will emerge by 2020.

OBJECTIVE

The key objective is to maintain the voltage as appropriate per the standards in the relevant jurisdiction on the transmission networks. Specifically, this means ensuring that voltages are maintained within acceptable voltage ranges on both the transmission system. In addition, the performance of the system following voltage steps and disturbances must remain within the necessary limits and recovery should be achieved in a timely manner.

WORK COMPLETED

Grid Code Modifications

The work of the DS3 Grid Code workstream formed the basis of the first phase of the Voltage Control workstream in developing and bringing forward changes to the reactive power standards of WFPSs as summarised below:

> **Reactive Power Control Modes**: requires wind farms to be capable of operating in Power Factor control, Reactive Power control or Voltage Regulation Set-Point control modes.

[1] http://www.eirgrid.com/media/Ensuring_a_Secure_Reliable_and_Efficient_Power_System_Report.pdf

Steady State Reactive Power Capability: requires wind farms to provide a Q/Pmax ratio of 0.33 down to 12% of Registered Capacity and to deliver this capability at the Connection Point (as opposed to the LV terminals of the Grid transformer).

Fault Ride-Through: requires wind farms to recover their active power output within 500 ms of fault clearance (previously 1 s) and requires them to provide reactive current within 100 ms of fault inception. It also allows for the reactive response to be tuned if over-voltages occur.

The Ireland Grid Code modifications were approved by the CER on 26th February 2013. The Ireland Distribution Code modifications were approved by the CER on 8th October 2013. The WFPS Setting Schedule in Northern Ireland was approved by URegNI on 29th October 2013.

It should be noted that the development of enhanced standards for conventional generation plant on the transmission and distribution systems was not seen as offering any significant benefit and was subsequently not progressed by the respective Grid Code Review Panels.

TSO Analysis

The TSOs undertook a number of studies that considered the impact of embedded WFPSs on transmission voltage performance based on the new WFPS voltage/reactive capability.

The first study 'Reactive Power from Wind Farm Clusters' (March 2013) considered the performance of a number of different voltage/reactive power control regimes (based on the new WFPS Grid/Distribution Code requirements) at a number of WFPS clusters. The report presented a simple methodology for determining a static power factor setting that would compensate for the distribution network and indicated that embedded WFPS operating in voltage control would deliver additional advantages although would perhaps present greater implementation challenges.

The second study 'Voltage Stability Studies: Analysis of the Donegal Area' (October 2013) considered the regional impact on voltage control of an area with significant levels of WFPS penetration. The report indicated that the present practice of embedded WFPSs operating at a leading (absorbing) power factor risked potential voltage collapse of the region but that by moving towards operation of WFPSs in voltage control mode, the voltage stability of the network could be significantly improved.

TSO-DSO Engagement

The TSOs and DSOs engaged throughout 2013 on the development of a 'Voltage Control Work Plan' as discussed in the next section.

FOCUS AREAS 2013 – 2015

Implementation of New WFPS Capabilities

Given the approval of the WFPS DS3 modifications in 2013, a programme of implementation of the new standards on wind farms with associated testing/validation has been initiated. The TSOs will manage this process for transmission-connected wind farms through the TSOs' Grid Code

compliance and testing processes. The DSOs will manage this process for distribution-connected wind farms.

Wind farm models and study methodologies used by the TSOs and DSOs will need to be updated as appropriate to reflect new reactive power standards. The impact of these changes will need to be considered in the real-time analysis of the power system by the TSOs, the studies conducted to assess new wind farm connections and in the planning of the transmission and distribution networks by the TSOs and DSOs.

TSO Reactive Power Planning

Studies will be undertaken by the TSOs to determine the medium to long-term reactive power requirements of the transmission system including sensitivities of the voltage control arrangements implemented on embedded WFPSs.

TSO-DSO Engagement

The TSOs and DSOs have agreed a voltage control work-plan for 2013 through to 2015 to work together to identify and develop suitable demonstration projects to trial the operation of the new wind farm standards and control principles. These projects will provide practical examples of how the new capabilities can be utilised and, along with the principles agreed between the TSOs and DSOs will form the basis of future operating protocols that will set out in detail how the TSOs and DSOs cooperate to maintain transmission and distribution voltages within standards.

The following sections set out the original workstream plan as published in December 2011

SCOPE

The scope of this work-stream can be broken into three phases of work. These are as follows:

1. Setting appropriate standards for reactive power capability and control on connecting generation both renewable plants and conventional plant
2. Designing the network while allowing for changed capabilities of connecting generation, particularly embedded in the distribution system
3. Developing appropriate system operational policies to utilise this capability, fully co-ordinated between the transmission and distribution systems of Ireland and Northern Ireland.

1. PHASE 1: REACTIVE POWER STANDARDS (2012 & 2013)

This work area will examine whether standards relating to voltage control need to be updated/clarified for both transmission- and distribution- connected generation. This will involve consultation and discussion leveraging the industry instruments already set up under the appropriate Grid Codes and Distribution Codes in Ireland and Northern Ireland. In addition there will

be a review, where necessary, to examine where these standards are best placed including Connection Agreements, Grid and Distribution Codes.

Steady state Reactive Capability and Voltage Control Modes for Renewable Generators

In order to provide improved operational flexibility to the TSOs in terms of voltage control for increasing number of Controllable WFPS on the Power System, three modes of operation for renewable generators are required in Ireland and Northern Ireland, i.e. 'Q-Mode' or Reactive Power / Mvar Instruction, Power Factor control modes, and Voltage Control with feedback. This, or a relevant standard need to be decided on in the short-term and the standard clarified going forward for all wind farms, both transmission- and distribution-connected, Ireland and Northern Ireland. This workstream will also review the reactive capabilities of new technologies to meet the needs of the system.

Steady State Reactive Capability and Voltage Control Modes for embedded conventional plant

Conventional plant in distribution networks currently has a relatively restricted requirement to provide reactive power control. This needs to be examined in light of the review on wind farms and a decision made should the standards for new embedded conventional plant change.

Dynamic Reactive Power Provision from transmission and distribution connected wind farms

The recent Facilitation of Renewables study showed that the transient stability of the power system would be degraded at very high wind penetrations if sufficient reactive support was not provided. However, the studies showed that these issues can be largely mitigated if wind farms act quickly to restore active power output after fault clearance. In addition, this workstream will optimise the injection of active and reactive currents during faults to maintain voltage stability. This work task will seek to define the requirements for wind farm plant in both the transmission and distribution systems in this regard. While there is a desire to standardise the requirements as much as possible, there may be challenges that require different standards. These issues will be identified and addressed in this workstream.

Covered off by Grid Code workstream

Dynamic Reactive Power Provision for transmission and distribution conventional plant

The capability of conventional plant to assist during voltage disturbances has a material impact on the integrity of the power system during disturbances. An examination of these standards is required to ensure that they are sufficient for the long-term security of the system at high penetrations of wind generation.

Covered off by Grid Code workstream

Controllability of Wind farms

The lack of control of existing wind farms in Ireland, particularly in terms of reactive power, was highlighted as a source of concern in the recent DS3 Report. As the levels of connected wind continue to increase, the continued monitoring of this voltage control capability is essential to ensure that the appropriate standards are adhered to. Key to this is Grid Code compliance testing

and on-going performance monitoring of all wind farms to ensure control is maintained throughout their operational lifetime.

Covered off by Performance Monitoring workstream

2. Phase 2: System operation allowing for changing capabilities of Generation and Wind Farms (2013 & 2014)

This phase will consider the implications of any changes in terms of studies and operation of the system following on from changes in phase 1.

Pilot Projects

Some of the changes in standards made (e.g. reactive capability of embedded generation or change in control modes of wind farms) per Phase 1 of this workstream may need to be trialled on a test basis. The TSOs will work with the DSOs to trial this. In particular, demonstrations of how new voltage control modes on wind farms embedded in the distribution system can be used to manage both distribution and transmission system voltage. In addition, if voltage control capabilities are sought from embedded conventional plant this may need to be demonstrated in order to develop appropriate operational policies and practices for managing voltage control.

Planning Studies (TSO & DSO)

The methodology used for both TSO and DSO connection studies will need to be updated to reflect any changes in standards for embedded plant per the Grid Codes and Distribution Codes and how this impacts on future network connection studies and agreements.

Network Solutions (TSO & DSO)

When a clear understanding has been developed of what is expected (in terms of standards of performance) from new generation, modelling of the future network can be performed to examine what deficiencies remain and how the installation of network devices may contribute to alleviating these issues.

3. Phase 3: Developing Operational Policies (2014)

Following changes in standards and analysis of the impacts of these changes, new operational policies will have to be developed and in some cases, existing policies will have to be updated. For some policies, new tools will also have to be developed/updated.

TSO Reactive Power Management Policy

The voltage control practices currently in use in the Control Centres will have to be updated to take into account any changes in reactive power capability. Some of the control tools in use in the Energy Management System will have to be updated to take into account the change in reactive capability. Detailed studies will also have to be carried out in the operational timeframe to assess the impact of any changes. This policy will also need to consider the necessary system tools required to successfully implement these policies in real time.

TSO/DSO Voltage Control Policy

The power system is changing from one of bulk power generation and transmission to load centres into a system with high levels of embedded generation. This means that the transmission and distribution systems need to be capable of a much wider operating range: from peak demand with low embedded generation to minimum demand with high embedded generation. This is a fundamental shift and may increase the range of reactive power control that is required to maintain system voltages within limits.

The traditional method of voltage control on the distribution system is through the use of tap-changers on transformers, line drop compensators and down-line regulators. This method assumed that the voltage dropped away from the primary substation towards the load and was within a given power factor band.

There is an interaction between the actions the TSOs take to manage the High Voltage system and the actions the DSOs take to manage the Medium Voltage and Low Voltage systems. These actions need to be carefully co-ordinated to ensure secure voltage levels on the entire power system. Due to the changing nature of connecting generation, there is a need to investigate the best method for managing the co-ordination of TSO/DSO activities. The outcome of this is an agreed TSO/DSO reactive power operating protocol.

HIGH-LEVEL PLAN

TASK NO.	TASK	RESPONSIBLE	ORIGINAL DUE DATE	DUE DATE
Note: VC.09 and VC.10.05 through to VC.11.04 of the 2013 Voltage Control Work Plan have been re-planned and are now reflected in the new tasks below.				
Development & Implementation of New WFPS Capabilities				
VC.01	Decision: Steady state Reactive Power Control from wind farms	TSOs, DSOs	Q3 2012	Complete
VC.02	Engagement between TSOs and DSOs on universal wind farm standards and appropriate controls for embedded conventional plant	TSOs, DSOs	Q1 2012	Complete
VC.03	Grid Code and Distribution code changes brought to industry for discussion	TSOs, DSO, All	Q2 2012	Complete
VC.04	Decision: Steady-State Reactive Power Control for embedded conventional plant	TSOs, DSOs	Q2 2012	Complete
VC.05	Decision: Dynamic Reactive Power Provision from transmission- and distribution-connected conventional plant	TSOs, DSOs	Q4 2012	Complete
VC.06	Decision: Dynamic Reactive Power Provision from transmission- and distribution-connected wind farms	TSOs, DSOs	Q4 2012	Complete
VC.07	Controllability of Wind farms	TSOs, DSOs	On-going	On-going
VC.08	Complete implementation of new Grid & Distribution Code standards and consideration of retrospection	TSOs, DSOs	Q1 2014	Complete
PM&T.5.4	Develop standard processes based on new Grid Code modifications which require testing	TSOs	New Task	Q4 2014
PM&T.5.5	Consideration of standardised testing processes arising from Distribution Code Modifications	DSOs	New Task	Q4 2014
TSO Analysis and Policy				
VC.10.01	Review of relevant ENTSO-E Network Codes	TSOs	Q1 2013	Complete
VC.10.02	Review relevant legislation in Northern Ireland	TSOs	Q1 2013	Complete
VC.10.03	Review relevant legislation in Ireland	TSOs	Q1 2013	Complete
VC.10.04	Consolidate Network Code / legislation reviews	TSOs	Q1 2013	Complete
VC.10.18	Study: 'Reactive Power from Wind Farm Clusters'	TSOs	Q1 2013	Complete
VC.10.19	Study: 'Voltage Stability Studies: Analysis of the Donegal Area'	TSOs	Q3 2013	Complete
VC.10.20	Study: Pilot PV (Power-Voltage) study at wind-farm cluster with existing operational practice to determine the level of reactive compensation required in the locality	TSOs	Q4 2013	Complete
VC.10.21	Develop methodology and approach to assessing system-wide reactive compensation requirements including input from DSOs on distribution network assumptions	TSOs, DSOs	New Task	Q1 2014
VC.10.22	Study: Complete system-wide reactive compensation requirement studies with sensitivities on operational practice	TSOs	New Task	Q3 2014
VC.10.23	Study: Transmission 'voltage trajectory'	TSOs	New Task	Q3 2014
VC.10.24	Deliver Transmission Voltage Control Policy (including agreed TSO-DSO protocol)	TSOs	Q1 2014	Q3 2015
TSO-DSO Engagement – Requirements				
TDV1.1	Develop common understanding of 2020 reactive power requirements and potential contribution of distribution-connected generation	DSOs / TSOs	New Task	Q1 2014
TDV1.2	Agreement on interim voltage control arrangements signalling and commissioning requirements pending development of the enduring arrangements	ESBN / TSO	New Task	Q1 2014
TDV1.3	Agreement on interim voltage control arrangements signalling and commissioning requirements pending	NIE / TSO	New Task	Q1 2014

	development of the enduring arrangements			
TDV1.4	TSOs to articulate preferred voltage control requirements for 'cluster' type stations	TSOs	New Task	Q4 2013
TDV1.5	DSOs consideration of TSOs preferred voltage control requirements and how/if they can be implemented in a DSO Nodal Voltage Control solution	NIE	New Task	Q1 2014
TDV1.6	DSOs consideration of TSOs preferred voltage control requirements and how/if they can be implemented in a DSO Nodal Voltage Control solution	ESBN	New Task	Q1 2014
TDV1.7	Agree approach to voltage control pilot project	NIE / TSO	New Task	Q1 2014
TDV1.8	Agree approach to voltage control pilot project	ESBN / TSO	New Task	Q1 2014
TSO-DSO Engagement – Analysis				
TDV2.1	Agee scope and location for Northern Ireland cluster study	NIE / TSO	Q1 2013	Q1 2014
TDV2.2	Agree scope and locations for Ireland cluster study	ESBN / TSO	Q1 2013	Q1 2014
TDV2.3	Exchange of appropriate models and data	NIE / TSO	New Task	Q1 2014
TDV2.4	Exchange of appropriate models and data	ESBN / TSO	New Task	Q1 2014
TDV2.5	TSO analysis complete and report shared	TSOs	New Task	Q1 2014
TDV2.6	DSO analysis complete and report shared	NIE	New Task	Q2 2014
TDV2.7	DSO analysis complete and report shared	ESBN	New Task	Q2 2014
TDV2.8	Recommendation (technical/commercial/priorities) to DSOs/TSOs Oversight Committee and decision on next steps	NIE / TSO	New Task	Q2 2014
TDV2.9	Recommendation (technical/commercial/priorities) to DSOs/TSOs Oversight Committee and decision on next steps	ESBN / TSO	New Task	Q2 2014
TSO-DSO Engagement – Pilot Projects				
TDV3.1	Scope pilot project	NIE / TSO	New Task	Q2 2014
TDV3.2	Scope pilot projects	ESBN / TSO	New Task	Q2 2014
TDV3.3	Pilot project approval	NIE / TSO	New Task	Q3 2014
TDV3.4	Pilot project approvals	ESBN / TSO	New Task	Q3 2014
TDV3.5	Commence pilot project	NIE / TSO	New Task	Q4 2014
TDV3.6	Commence pilot projects	ESB / TSO	New Task	Q4 2014
TDV3.7	Pilot project report & recommendations to DSOs/TSOs Oversight Committee	NIE / TSO	New Task	Q2 2015
TDV3.8	Pilot project reports & recommendations to DSOs/TSOs Oversight Committee	ESBN / TSO	New Task	Q2 2015
TSO-DSO Engagement – Policy				
TDV4.1	Recommendation to DSOs/TSOs Joint Oversight Committee for reactive power / voltage control arrangements for embedded (non-cluster) wind farms and decision on next steps	NIE / TSO	New Task	Q3 2014
TDV4.2	Recommendation to DSOs/TSOs Joint Oversight Committee for reactive power / voltage control arrangements for embedded (non-cluster) wind farms and decision on next steps	ESBN / TSO	New Task	Q4 2014
TDV4.3	Finalise TSO/DSO Voltage Control protocol	NIE / TSO	Q1 2014	Q3 2015
TDV4.4	Finalise TSO/DSO Voltage Control protocol	ESBN / TSO	Q1 2014	Q3 2015
General				
VC.12.01	Provide 2014 workstream progress update and develop workstream plan for 2015	TSOs	New Task	Q4 2014