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Modification proposal:	**Modification to the Grid Code: Constant Terminal Voltage (GC0028)**		
Decision:	The Authority[1] directs that the proposed modification to the Grid Code[2] be made		
Target audience:	National Grid Electricity Transmission PLC (NGET), Grid Code users and other interested parties		
Date of publication:	15 January 2016	Implementation date:	To be confirmed by NGET

Background

National Grid Electricity Transmission plc (NGET) is the System Operator (SO) for the National Electricity Transmission System (NETS). NGET is responsible for ensuring the stable and secure operation of the whole of the NETS. The Grid Code specifies the technical requirements for users connecting to, and using, the NETS.

The modification proposal centres on the requirements for onshore synchronous generating units' abilities with regards to provision of reactive power and how they undertake voltage control. The Grid Code Connection Conditions (CC.6.3.2) set out the operating requirements for synchronous onshore generating units' power factor capability, 0.95 leading to 0.85 lagging.[3] CC.6.3.4 sets out that the power factor requirements must be met across a voltage range of ±5% at 400kV, 275kV, 132kV and lower. CC.6.3.8(a)(i) specifies that the synchronous generating unit's terminal voltage must be constant. The Grid Code Balancing Code (BC2.A.2.6) specifies that the MVAr[4] level instructed by the SO must be met within a specific tolerance, usually ±25MVAr although other tolerances may apply in Scotland.

When these four sections of the Grid Code are taken together, it can be problematic for large generating units to achieve the necessary power factor requirements using standard equipment. A number of derogations are in force in relation to this issue. This requirement also presents particular challenges for future generating units that could be up to 1800MW capacity.

The present method of reactive power control required by the Grid Code for affected plant utilises on-load tap changers on the generating unit transformer whilst maintaining constant terminal voltage on the generating unit itself. NGET investigated alternative methods of voltage control, including international examples, and assessed their efficacy; this included the French model where reactive power control is carried out solely by controlling the generating unit's terminal voltage. Following these investigations, NGET raised a Grid Code issue to explore possible options for remedying the problem identified.

The modification proposal

GC0028 (the "modification proposal") was raised by NGET with the Grid Code Review Panel (GCRP)[5] in July 2013. A Workgroup was formed to examine the issue in November 2013.

[1] The terms 'the Authority', 'Ofgem' and 'we' are used interchangeably in this document. Ofgem is the Office of the Gas and Electricity Markets.
[2] This document is notice of the reasons for this decision as required by section 49A of the Electricity Act 1989.
[3] Power factor is defined as the ratio of real power to the apparent power. A leading power factor denotes a capacitive system supplying reactive power whilst a lagging power factor denotes an inductive system consuming reactive power.
[4] Volt Amperes reactive (VAr) is the unit used to describe reactive power.
[5] GCRP Issue Paper – "Constant Terminal Voltage" – 3 July 2013.

As part of the investigation into solutions to the problem raised in the Issue Paper, NGET carried out extensive modelling and simulation. NGET also carried out studies into the possibility of terminal voltage control only and found that, to ensure the required level of reactive power control, a voltage range of ±11% would be needed. This is infeasible as it would have a detrimental impact on the supplies for auxiliary equipment in the power stations. To ensure adequate supplies for auxiliaries, a range of ±3% is required. This voltage restriction fed into the options assessed below.

Four possible solution options were assessed by the Workgroup:

- Option 1 – Maintain the existing Grid Code requirements

Modelling was carried out to determine the impact of current practice on large units, such as 1800MW units that may be used in the new fleet of nuclear generating stations in the future. It was found that an infeasibly large number of taps (in excess of 100) would be needed on the generating transformers' on-load tap changer (OLTC[6]). This would mean designing bespoke systems and building them for these generating units, increasing the risk of failure to the plant in question. Another problem identified with this solution would mean a significant time lag (50-100 minutes) between NGET issuing an instruction and the generating unit complying with it, when NGET needed to move from one extreme of the operating envelope to the other. This option was therefore rejected.

- Option 2A – Mix of OLTC control and terminal voltage control, only at extremes of reactive power requirement

The generating unit transformer would have an OLTC with a smaller range of taps than in Option 1. To ensure that the plant met its reactive power requirements, generator terminal voltage control would be used at the extremes of operation only. In effect, the OLTC would offer primary reactive power control so that generator terminal voltage control would only be used in circumstances where operation was required at the extremes of the reactive power control envelope. This solution has problems with the required reactive power output accuracy (±25MVAr) which means that the step size between taps would be very small and potentially unrealistic. This option was also therefore rejected.

- Option 2B – Mix of OLTC control and terminal voltage control, across all reactive power requirements

Option 2B is very similar to 2A but allows the terminal voltage to be varied at any operating point within the reactive power envelope. One issue raised with this option relates to the maximum size of step between taps. The maximum voltage step allowed on the 400kV system is 4kV, so a restriction would be needed on the design of the OLTC for new generating units to ensure that the voltage step change was kept within this limit. By utilising terminal voltage control, it may be possible to achieve a step change of 1kV to assist with this problem. This option was taken forward as the preferred solution and is the basis of the modification proposal.

- Option 3 – Modification of the reactive power requirements in Grid Code

Option 3 proposed that the reactive power requirements for synchronous onshore generating units, operating at extreme voltage conditions, should be reduced. This would allow a reduction in the number of taps in the OLTC. The issue of reactive power

[6] OLTCs are equipment used on transformers that allow the number of windings in circuit to be changed. By changing the number of windings, the ratio of high voltage to low voltage windings is altered and as a result the output voltage changes accordingly.

capability at extremes of voltage was investigated. Events were identified where these capabilities had been required in the past. More importantly, it was found that they could also be required in the future. Therefore, reducing the reactive capability of these generating units would mean that additional investment would be needed to ensure dedicated dynamic reactive compensation plant was available. This alternative would have higher costs than the other options presented. As a result, option 3 was rejected.

The final modification proposal is based on option 2B. Provision has been made that synchronous generating units can utilise a mixture of OLTC and terminal voltage control to provide the reactive power capabilities as set out in the Grid Code. The proposal states that these changes can only be used when set out in the bilateral connection agreement. Terminal voltage control range is restricted to 1PU or above.[7] The reason for this restriction is based upon modelling that shows that a reduction in terminal voltage has an adverse impact on transient stability compared to utilisation of the OLTC only.

Option 2B allows generators the flexibility to supplement transformer tap changer control with machine terminal voltage adjustment when responding to an MVAr instruction. Generators will have more flexibility when specifying their generating unit transformers, will be able to move spare transformers between sites, and will be able to avoid the need to use transformers with an excessive, potentially unrealistic, number of taps.

A Workgroup report recommending option 2B was submitted to the GCRP in May 2015. The proposal was progressed through an industry consultation published in July 2015. Two responses were received to the consultation paper, both of which fully supported the modification proposal, with no concerns highlighted.

NGET's recommendation

NGET issued its GC0028 final report to us on 25 November 2015. The final report recommends the introduction of terminal voltage control in conjunction with OLTC control for reactive power control. NGET considers that this option will resolve the issue of large synchronous generating plant achieving the required reactive power capabilities. The modification proposal assumes that an OLTC will be available to provide coarse MVAr control output. MVAr output will then be finely tuned by adjusting the machine terminal voltage through the automatic excitation control system.

NGET considers that the proposal will better facilitate Grid Code Objectives (i), (ii) and (iii) as it relates to improving the control of transmission system voltage and therefore impacts on development and operation of the system as well as on system security. NGET also considers that GC0028 has a neutral impact on Grid Code Objective (iv).

Our decision

We have considered the issues raised by the modification proposal and the Final Report dated 25 November 2015. We have considered and taken into account the responses to NGET's consultation on the modification proposal which are included in the Final Report.[8] We have concluded that -

- implementation of the modification proposal will better facilitate the achievement of the objectives of the Grid Code;[9] and

[7] 1PU refers to the rated value of the generator's terminal voltage consistent with its design.
[8] Grid Code proposals, final reports and representations can be viewed on NGET's website at: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/Grid-code/Modifications/
[9] As set out in Standard Condition C14(1)(b) of NGET's Transmission Licence, available at: https://epr.ofgem.gov.uk/

- approving the modification is consistent with our principal objective and statutory duties.[10]

Reasons for our decision

We consider this modification proposal will better facilitate Grid Code objectives (i), (ii) and (iii), and has a neutral impact on objective (iv).

Objective (i) 'to permit the development, maintenance and operation of an efficient, co-ordinated and economical system for the transmission of electricity'

NGET explained that the proposal would reduce the need, in some situations, for an excessive number of taps on generating transformer OLTCs for large generating units. The modification proposal shows that requiring a very large number of taps would mean developing bespoke technology for future large (ie up to 1800MW) generators. It would also cause issues for the SO when issuing voltage set point instructions, due to the length of time it would take to change reactive power output from one extreme to the other. The modification proposal sets out a method that allows for a much smaller range of taps for new generators. Also, for existing generators, it allows the utilisation of equipment already present to achieve the requirements of the Grid Code. This will potentially remove the need for a number of current derogations. By utilising more standard equipment, generators can also swap transformers or move them from site to site if needed in future.

In our view, the modification proposal improves the development, maintenance and operation of the transmission system. Allowing standard equipment to be used improves the development of the system by reducing the risks posed by unproven bespoke equipment. By utilising standard equipment, maintenance is also improved. The operation of the system is improved by allowing existing derogated and future plant to meet the requirements of the Grid Code. For these reasons, we consider that GC0028 better facilitates this objective.

Objective (ii) 'to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity)'

The current system for reactive power control is potentially difficult for large units to achieve and, as a result, there are a number of derogations in force relating to the issue of voltage control. By allowing alternative methods to control reactive power, these derogations may be lifted. The modification proposal allows more flexibility for a generator in how it is designed and the specification of plant to achieve the Grid Code requirements. By providing this level of freedom and flexibility, costs can be reduced and this could encourage innovation and competition between generators. We therefore consider that GC0028 better facilitates this objective.

Objective (iii) 'subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole'

Voltage control on the transmission system is a vital aspect of the SO's role. Synchronous generating plant can be considered to be the "pillars" of voltage control on the system.

[10] The Authority's statutory duties are wider than matters which NGET must take into consideration and are detailed mainly in the Electricity Act 1989 as amended.

By ensuring that new large-scale generating units can comply with the voltage control requirements in the Grid Code, the security of the system is improved. If they were not able to provide the voltage support necessary, significant investment in dedicated dynamic voltage control equipment on the system would be required at a greater economic cost. By ensuring that these generating units can provide the voltage support necessary at a lower cost, the modification proposal does better facilitate objective (iii).

Decision notice

In accordance with Standard Condition C14 of NGET's Transmission Licence, we approve Grid Code modification GC0028 *'Constant Terminal Voltage'*.

We direct that GC0028 is implemented on a date to be confirmed by NGET.

Gareth Evans
Head of Profession – Engineering
Signed on behalf of the Authority and authorised for that purpose