Offshore Transmission Expert Group
Great Britain Security and Quality of Supply sub-group

Voltage Limits for Planning and Operation of Offshore Transmission Networks

Introduction

This paper sets out options for planning and operational voltage limits, reactive power requirements and automatic voltage control requirements for offshore transmission networks. This paper has been produced in response to a review of chapter 6 of the GB SQSS – Voltage Limits in Planning and Operating the *GB transmission system.*

This paper has taken consideration of existing arrangements in England, Wales and Scotland, and puts forward a number of options for offshore transmission networks. It should be noted that the existing (onshore) GB SQSS voltage limits always apply at any onshore transmission substation to which an offshore transmission network is connected. However, different voltage limits could be considered within the offshore network. This paper considers the following three options for offshore voltage limits:

1. Voltage limits are the same as for onshore networks.
2. No voltage limits are explicitly set in the offshore GBSQSS.
3. New voltage limits are set for offshore networks.

The connection of an offshore network to an onshore system should not place excessive reactive power transfer requirements on the onshore network. Voltage control and reactive power requirements for the onshore/offshore interface are also discussed below.

The voltage limits proposed below are appropriate for AC offshore networks and would not apply to HVDC installations. However, an HVDC converter would be expected to meet the Grid Code requirements at the point of connection to an onshore network (or at the point of connection to an offshore AC transmission system).

Voltage limits at the offshore platform

Option 1: Limits the same as for onshore values

For option 1, the existing onshore voltage limits from the GB SQSS (section 6) are simply adopted for offshore transmission networks.

The advantages and disadvantages of this approach are summarised below:

Advantages	Disadvantages
1. Operational – no confusion due to range of different voltage limits. 2. Consistent with Grid Code requirements for generators.	1. Not all possible offshore voltage levels are covered, e.g. 220kV. 2. Probably not the lowest-cost option. 3. Voltage step limits quite onerous. 4. Compliance with ER P28 not really relevant for an offshore network (flicker unlikely to bother anybody).

For reference, a summary of the existing SQSS voltage limits is given in appendix A.

Option 2: No voltage limits

This option would not mean a complete lack of voltage limits, but rather limits that are individually set at the design stage of each offshore network (including operational voltage limits). Advantages and disadvantages are:

Advantages	Disadvantages
1. This arrangement would allow transmission owners to design systems according to the rating of the plant allowing for efficiencies of equipment purchase where possible. I.e. lowest capital cost option.	1. Operational difficulties (different limits for different sites would be confusing). 2. Could lead to inconsistency with Grid Code requirements. 3. There may be difficulties in maintaining a consistent approach to the identification and specification of site-specific limits. 4. Could lead to disputes in future. 5. Could result in narrower (rather than more relaxed) voltage limits, leading to operational difficulties. 6. Voltage limits may not be known for connection offer studies or could change before construction is started. 7. Different (site-specific) limits may be detrimental to standardisation of offshore generation design and operation.

Option 3: New voltage limits

Option 3 proposes a new set of voltage limits that are considered most appropriate for an offshore transmission network. The advantages and disadvantages of this approach are:

Advantages	Disadvantages
1. Fixed set of planning and operational voltage limits, although not the same as for onshore networks. 2. Clear, unambiguous offshore voltage limits for planning and operational time-scales. 3. Relaxing the offshore voltage limits could lead to a lower cost solution, overall. 4. Clear, specific limits could be set to minimise future interpretation issues (that could arise e.g. if the existing GB SQSS section 6 were adopted without modification).	1. Could lead to inconsistency with Grid Code requirements. 2. Differences between onshore and offshore limits may cause confusion, particularly in operational timescales.

Tables 1 and 2 show initial suggestions for offshore voltage limits. The steady-state voltage limits are generally consistent with the limits in the GB SQSS (see tables 6.1, 6.3 and 6.5 of the GB SQSS), while the voltage step limits have been relaxed.

Table 1. Proposed offshore voltage limits in planning and operational timescales.

Time-scale	Voltage Limits < 132kV Min	Max	132kV – 200kV Min	Max	> 200kV Min	Max
Pre-fault planning	105% at transformer LV	105%	105% at transformer LV	105%	95%	105%
Post-fault steady state planning	100% at transformer LV	105%	100% at transformer LV	105%	90%	105%
Pre-fault operational **Note 1**	95%		95%		95%	
Post-fault steady state operational	94%	106%	90%	110%	90%	110%

Notes
1. See SQSS clause 6.6.

Table 2. Proposed offshore voltage step change limits in planning and operational timescales.

	Voltage Fall	Voltage Rise
Following a secured event **Note 1**	-6% **Note 2**	+6%
Following operational switching	-6%	+6%

Notes
1. This could be an onshore or an offshore event.
2. This is relaxed to –12% if the fault involves the loss of a double circuit, a section of busbar, a mesh corner or a supergrid transformer.

Option analysis

Although option 1 (retaining the onshore voltage limits) is the most straightforward solution, tables 6.1, 6.3 and 6.5 of the GB SQSS would have to be adapted to accommodate a range of possible offshore nominal voltage levels. The onshore voltage step change limits, particularly the requirements of Engineering Recommendation P28, are very onerous for an offshore windfarm installation, where flicker will not cause a disturbance. Therefore, option 1 is not recommended.

Option 2 would give designers the freedom to select the optimal voltage limits for each offshore installation. This is therefore likely to be the lowest capital cost option. However, this is likely to lead to operational problems:
(a) Operational staff has to keep track of different offshore voltage limits, increasing the risk of errors.
(b) Voltage limits might be difficult, costly or impossible to meet operationally.

Although option 2 is likely to be the lowest capital cost option, the operational risks are considered too high and this option is not recommended.

Option 3 proposes steady-state voltage limits that are broadly similar to the existing onshore limits, while relaxing the voltage step requirements (see tables 1 and 2). This option would provide a fixed set of offshore voltage limits covering a broad range of nominal voltages, ensuring certainty at the design stage and operationally. It is therefore recommended that option 3 be adopted for the offshore SQSS.

Voltage limits at the point of interface with onshore system

The connection of an offshore network to an onshore system should not place excessive reactive power transfer requirements on the onshore network. Reactive power swings, as the output of the windfarm changes, are of particular concern. This section considers some of the issues related to the onshore/offshore interface in more detail.

The existing arrangements in Great Britain would place Grid Code Connection Conditions on onshore and offshore generators and DC Converters proposing a connection to the onshore electricity network. These obligations apply at the onshore Grid Entry Point or User System Entry point as shown in figure 1, and specify the requirements of the generator and DC Converter along with the network conditions they are connecting to.

Connection Conditions CC.6.3.2(b), CC.6.3.2(c) and CC.6.3.8(c) specified in the Grid Code are applicable to any windfarm applying for connection to the onshore electricity network (see appendix B). These clauses specify the reactive power capability requirements and the automatic voltage control requirements at the onshore point of interface.

Unless an offshore transmission system interconnects two or more onshore substations, it can be considered as a radial network connecting one or more offshore windfarms to the onshore system. From the point of view of the onshore system, the offshore transmission system and wind generation is “equivalent” to an onshore windfarm and its circuits to the onshore connection point. Therefore, it is reasonable to assume that clauses CC6.3.2(b), CC.6.3.2(c) and CC.6.3.8(c) should apply to the offshore transmission system at the onshore/offshore interface point.

Following established principles, reactive power capability and voltage control requirements at the onshore/offshore interface would normally be covered in the Grid Code and not in the security standards. However, because of their significant impact on the planning of the offshore transmission system, it is recommended that they should be specified or referenced within the offshore SQSS.

This recommendation would place a responsibility for providing reactive power capability and automatic voltage control capability at the onshore substation on the offshore TO. This includes the requirement to provide the necessary reactive compensation plant to maintain zero transfer of reactive power at the onshore/offshore interface for all wind farm active power outputs from Rated MW down to zero. Further, it may be more cost effective and efficient for the offshore TO to plan and install reactive compensation at the onshore and/or offshore substation, instead of requiring the offshore generator to provide reactive compensation at the point of connection to the offshore network. Therefore, there seems to be room to relax the Grid Code requirements for offshore wind generators and it is recommended that these requirements should be reviewed, taking account of the new requirements placed on the offshore TO. It may be preferable to apply the Grid Code requirements for generators at the generator/offshore transmission system interface and this consideration should also be included in the review.

Recommendation

This paper has considered voltage and reactive power requirements for offshore transmission networks, bearing in mind the existing requirements of the Grid Code and the GB SQSS. This review was required to ensure that the offshore transmission network is planned and operated in an economic and efficient manner. Figure 2 shows a summary of the recommendations and where these apply.

With offshore transmission systems connected to the onshore electricity network, there will be an additional interface to be specified. The following states the recommendations at the point of connection to the onshore electricity network and illustrates these against existing arrangements:

Existing arrangements

- Generator has Grid Code obligations at connection point
- Grid Code states onshore system conditions at connection point
- Onshore GB SQSS states voltage limits of onshore substation

Proposed arrangements

- Generator has Grid Code obligations at the point of connection to offshore TO
- Offshore GB SQSS states offshore system conditions at points of interface with external systems, to include but not be limited to reactive power and automatic voltage capability at the onshore/offshore interface, and offshore voltage limits.
- Onshore GB SQSS states voltage limits of onshore substation

At offshore substations, it is recommended that the steady state and voltage step change limits given in tables 1 and 2 be adopted. The steady state limits are broadly similar to the existing onshore limits, while relaxing the voltage step requirements.

This recommendation is made in conjunction with existing Grid Code requirements. From these requirements it is reasonable to assume that they should apply in full to offshore transmission systems. This will therefore require the existing Grid Code requirements for reactive power transfer and voltage control capability to be duplicated from the Grid Code and stated in the offshore transmission security standards. It should be noted that the Grid Code requirements on generators connecting to the offshore transmission system are yet to be determined and should be reviewed taking account of the new requirements placed on the offshore TO.

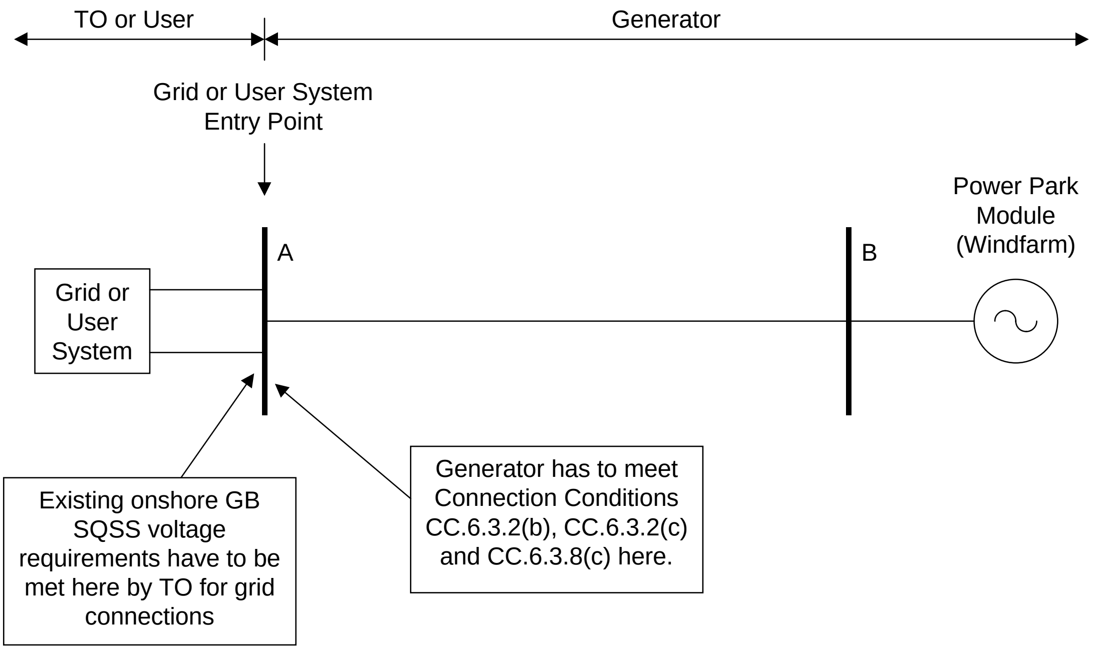

Figure 1. Existing Grid Code requirements for onshore wind generators.

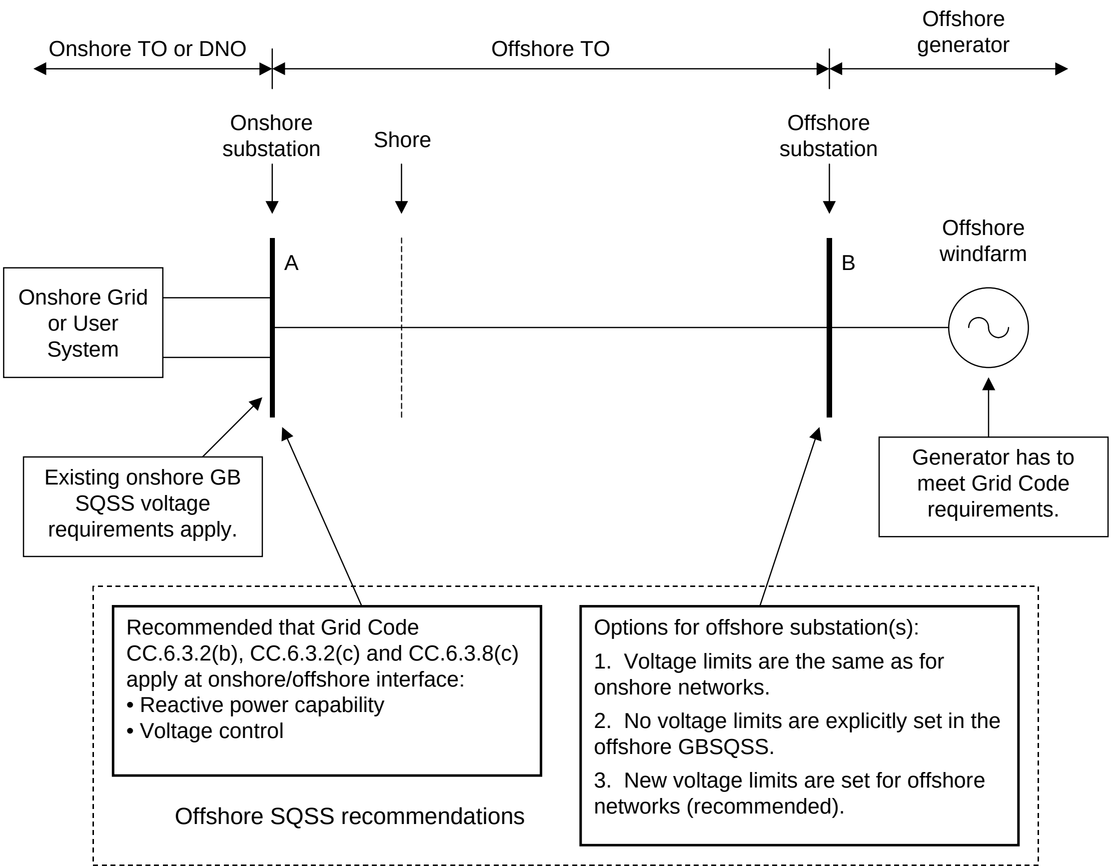

Figure 2. Options considered and recommendations for offshore SQSS voltage limits.

Appendix A

Table A.1. Summary of existing onshore GB SQSS steady state voltage limits.

	Voltage Limits					
Time-scale	< 132kV		132kV		275kV	
	Min	Max	Min	Max	Min	Max
Pre-fault planning	105% at transformer LV	105%	105% at transformer LV	105%	95%	105%
Post-fault steady state planning	100% at transformer LV	105%	100% at transformer LV	105%	90%	105%
Pre-fault operational *(see SQSS clause 6.6)*	95%		95%		95%	
Post-fault steady state operational	94%	106%	90%	110%	90%	110%

Table A.2. Onshore voltage step-change limits in planning and operational time-scales.

	Voltage Fall	**Voltage Rise**
Following a secured event	-6% (-12% under some conditions)	+6%
Following operational switching less frequent than specified in ER P28	-3%	+3%
Operational switching of frequencies covered by ER P28	In accordance with ER P28	In accordance with ER P28

Appendix B

*CC.6.3.2(b) Subject to paragraph (c) below, all **Non-Synchronous Generating Units, DC Converters** and **Power Park Modules** must be capable of maintaining zero transfer of **Reactive Power** at the **Grid Entry Point** (or **User System Entry Point** if **Embedded**) at all **Active Power** output levels under steady state voltage conditions. The steady state tolerance on **Reactive Power** transfer to and from the **GB Transmission System** expressed in MVAr shall be no greater than 5% of the **Rated MW.***

*CC.6.3.2(c) all **Non-Synchronous Generating Units, DC Converters** (excluding current source technology) and **Power Park Modules** (excluding those connected to the **Total System** by a current source **DC Converter**) must be capable of supplying **Rated MW** output at any point between the limits 0.95 **Power Factor** lagging and 0.95 **Power Factor** leading at the **Grid Entry Point** in England and Wales or at the HV side of the 33/132kV or 33/275kV or 33/400kV transformer for **Generators** directly connected to the **GB Transmission System** in Scotland (or **User System Entry Point** if **Embedded**). With all **Plant** in service, the **Reactive Power** limits defined at **Rated MW** at Lagging **Power Factor** will apply at all **Active Power** output levels above 20% of the **Rated MW** output as defined in Figure 1. With all **Plant** in service, the **Reactive Power** limits defined at **Rated MW** at Leading **Power Factor** will apply at all **Active Power** output levels above 50% of the **Rated MW** output as defined in Figure 1. With all **Plant** in service, the **Reactive Power** limits will reduce linearly below 50% **Active Power** output as shown in Figure 1 unless the requirement to maintain the **Reactive Power** limits defined at **Rated MW** at Leading **Power Factor** down to 20% **Active Power** output is specified in the **Bilateral Agreement**. These **Reactive Power** limits will be reduced pro rata to the amount of **Plant** in service.*

*CC.6.3.8(c) In the case of a **Non-synchronous Generating Unit, DC Converter** or **Power Park Module** a continuously-acting automatic control system is required to provide control of the voltage (or zero transfer of **Reactive Power** as applicable to CC.6.3.2) at the **Grid Entry Point** or **User System Entry Point** without instability over the entire operating range of the **Non- Synchronous Generating Unit, DC Converter** or **Power Park Module**. In the case of a **Power Park Module** in Scotland, voltage control may be at the **Power Park Unit** terminals, an appropriate intermediate busbar or the **Connection Point** as specified in the **Bilateral Agreement**. The automatic control system shall be designed to ensure a smooth transition between the shaded area bound by CD and the non shaded area bound by AB in Figure 1 of CC6.3.2 (c). The performance requirements for this automatic control system will be specified in the **Bilateral Agreement**.*