

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

**Recommendations for the coverage of  
offshore transmission networks in the  
Great Britain Security and Quality of Supply Standard**

## Summary

1. This paper sets out the recommendations of the GB Security and Quality of Supply (GBSQSS) sub-group for the coverage of offshore transmission networks in the GBSQSS (a copy of the Terms of reference for the sub-group along with a list of members can be seen in appendices 1 and 2 respectively). The paper also describes the methodology used, the results of its assessment and provides a description of the sensitivity analysis carried out to validate the recommendations made.
2. Consistent with other security standards, a cost benefit analysis approach was used to determine the optimum economic and technical security standard for offshore transmission networks. The analysis identified key parameters which impacted on the proposed solution and considered a large number of permutations to demonstrate the robustness of the recommendations against varying input data.
3. Based on the results of this analysis, it is considered that the onshore GBSQSS planning and operational standards:
  - a) are not appropriate for application to offshore transmission network development; and
  - b) require amendment to facilitate the inclusion of offshore transmission networks
4. These recommendations have taken account of a number of working assumptions which have been developed to determine the optimum economic solution for offshore transmission networks.
5. The recommendations made by the sub-group are:
  - a) The security standard for the offshore transmission network can be separated into two main sections:
    - i) The offshore platform (i.e. the AC transformer circuits, platform LV interconnection circuits and HVDC converters on the offshore platform); and
    - ii) The offshore cable network (i.e. the transmission cable circuits linking the onshore network and the offshore platform).Each should be considered separately for single and multiple wind farm connections<sup>1</sup>.
  - b) For single wind farm connections, both the offshore platform and cable network capacity should, at a minimum, be equal to the maximum export<sup>2</sup> capacity of the wind farm connected, with appropriate advice when less capacity can be installed.

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<sup>1</sup> The number of wind farms (single or multiple) can be determined by the number of users connected to the offshore transmission network.

<sup>2</sup> The maximum export capacity of the generator is equal to the system access provided

- c) For multiple wind farm connections, both the offshore platform and cable network capacity should, at a minimum, be equal to 90%<sup>3</sup> of the cumulative installed capacity of the wind farms connected.
  - d) For wind farms with a capacity of 120MW or greater, following an outage (planned or unplanned) of any offshore platform AC transmission circuit, there should be, at a minimum, be 50% of the installed platform export capacity remaining.
  - e) For wind farms connected using HVDC technology, following an outage (planned or unplanned) of any single offshore platform DC converter module, the loss of power infeed shall not exceed the existing onshore Normal Infeed Loss Risk. (1000MW<sup>4</sup>).
  - f) For outages (planned or unplanned) of offshore transmission circuits (i.e. offshore transmission AC and DC cables) the loss of infeed should not exceed 1500MW<sup>5</sup>.
6. In line with the existing GBSQSS, it is recommended that the offshore transmission security standards allow the transmission licensee to meet a Generator's request for security above or below the minimum planning standard provided there is no adverse impact on any other user, the Main Interconnected Transmission System (MITS) or the GB transmission licensees.
  7. In making this recommendation it is noted that there could be significant generation connected via a single offshore transmission cable circuit, resulting in a risk to the generator and/or offshore transmission System Operator (SO). The consequential impact of this recommendation on the access rights, compensation arrangements and transmission charging for offshore generation is outside the scope of work of the sub-group and has therefore not been considered.

## Background

8. The Ofgem scoping document on 'Offshore electricity transmission' published in April 2006 identified issues that required further consideration in implementing an offshore electricity transmission regime. The scoping document noted that this work should be taken forward in conjunction with government and industry through a working group, to be called OTEG (Offshore Transmission Expert Group).
9. At the OTEG meeting on 4 May 2006 it was decided to establish a sub group ('the GBSQSS sub-group') to undertake review work to assist Ofgem/DTI decisions relating to offshore transmission system security requirements. The GBSQSS sub-group report to OTEG who provide a single point of contact to address any issues that arise from the GBSQSS sub-group discussions.
10. The purpose of the GBSQSS sub-group is to assist OTEG by completing a review of the current GBSQSS and consequently considering:
  - a) whether it is appropriate to apply to the present onshore standard to offshore transmission networks
  - b) if amendments are needed to extend the GBSQSS offshore; and

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<sup>3</sup> This value is due to the cost of offshore transmission asset installation to the full capacity of connected wind farms given the probability that the windfarm will generate at full output due to wind diversity. Should this de-rating cause installation of assets that are marginally required, this value should be reviewed. Subsequently, transmission capacity lower than this amount could be installed provided it could be justified to be economic and efficient

<sup>4</sup> HVDC converter technology is not available for modules above 1000MW, therefore reliability and cost data was not available to assess this limit. Analysis has indicated that subject to the availability and reliability of larger converters it may be possible to increase this limit

<sup>5</sup> The 1500MW limit is bound by the scope in the cost benefit analysis. Should there be a requirement for a wind farm connection of a size greater than this, the value should be reviewed

- c) the range of options that exist for alternative security standards for offshore transmission networks.
- 11. The GBSQSS sub-group has noted the above requirements in undertaking a review of the security requirements for offshore networks. The existing GBSQSS was used as a basis to determine requirements for offshore transmission networks.
- 12. A full review of the standard can be seen in appendix 3, and has concluded that the areas that require detailed review for the inclusion of offshore transmission networks are:
  - a) Chapter 2 – Design of Generation Connections
  - b) Chapter 6 – Voltage limits in planning and operating the GB transmission system

## **Analysis work undertaken**

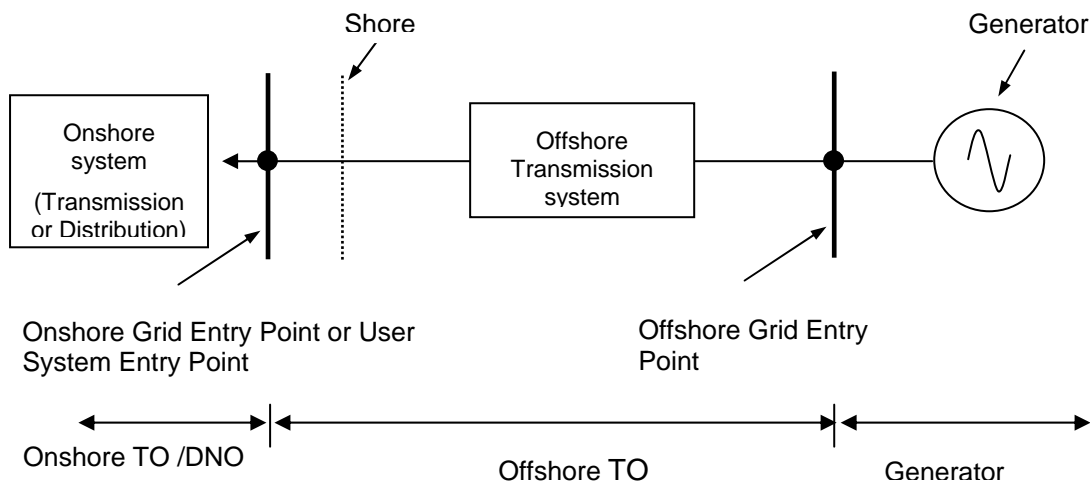
### ***Approach to the analysis***

- 13. The existing GBSQSS is based upon a security standard that has taken account of the need to build a transmission system that is economic, efficient, and resilient to all secured events stated, whilst also stipulating the maximum loss of power infeed that can occur for outages of transmission system assets.
- 14. A cost benefit analysis approach has been used to determine the optimum security standard for offshore transmission networks. This analysis has identified key parameters which impact on the proposed solution and considered a range of possible values to demonstrate the robustness of proposals against variation of input data.
- 15. This analysis has considered all wind farm connections presently anticipated to connect to an offshore transmission network, along with the characteristics of the assets to be installed in the network that will have an impact on the outcome of the analysis. Generic offshore wind farms have been modelled to include the consideration of single and shared, AC and DC connections. The objective of this analysis was to determine the optimum economic and technical solution for an offshore network connecting to the onshore electricity grid system.
- 16. For this analysis it is assumed that offshore transmission networks will be cable circuits for the connection from the offshore high voltage platform to the first substation that the circuit reaches onshore. A review of the proposed connection designs for a number of round 1 and 2 wind farms has been carried out to confirm this assumption and can be seen in annexe 3.
- 17. Only three relatively small offshore wind farm substations have been built worldwide so far and only one offshore HVDC converter station, therefore reliable outturn cost data is not available. Cost estimates based on recent competitive tenders have been provided by contractors through their trade body BEAMA Power Ltd.
- 18. The sub-group has verified the cost benefit analysis dataset, based on several series of data and using existing reports where available. Due to the uncertainties and number of assumptions that have had to be made, a comprehensive sensitivity analysis to test the validity of the recommendations to variations in key items of data has been performed. A full list of the data used in the analysis can be seen in Appendix 4.
- 19. The following key input parameters were varied to determine their critical point:
  - a) Transformer / cable Mean Time To Repair (MTTR)
  - b) Value of energy curtailed
  - c) Offshore substation distance from shore; and
  - d) Cable failure rates / reliability

20. These parameters were then compared to the cost of installing additional offshore assets. The analysis has considered the costs associated with the expected energy curtailed, but has not considered the apportionment of these costs.
21. As part of the GBSQSS review, an assessment of all work of a similar nature was carried out to ensure the cost benefit analysis work was consistent with published reports. A comparison to the KEMA 'Connect I' and 'Connect II' reports has been carried out, and it was concluded that the analysis carried out by the sub-group is consistent with that of the KEMA reports.

**Scope**

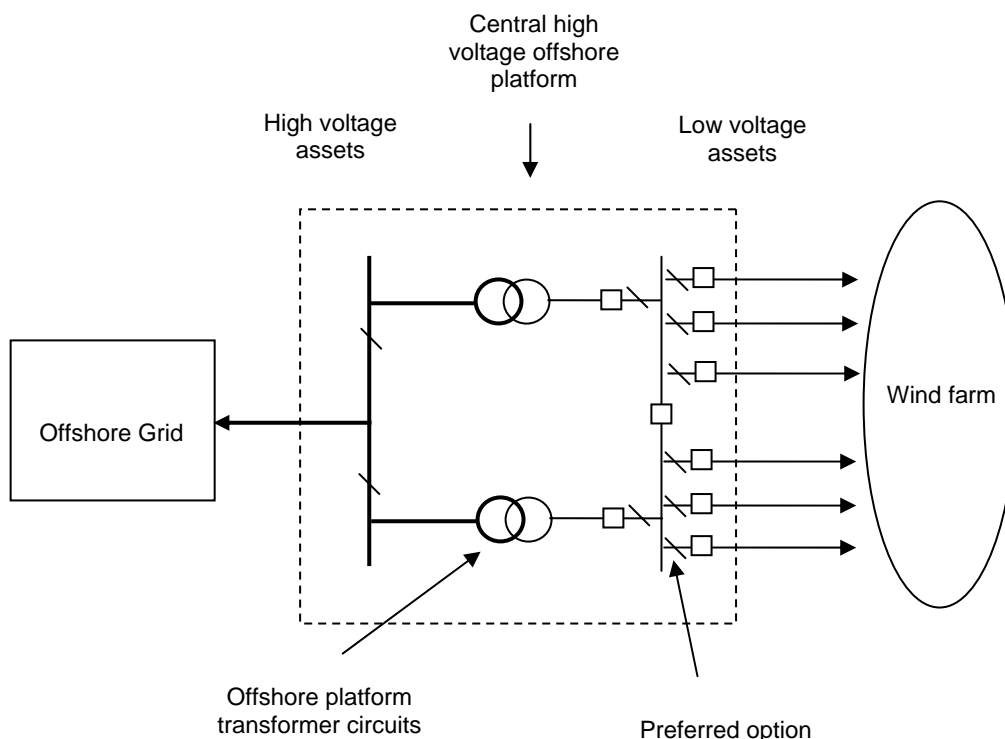
22. The GBSQSS sub-group reviewed the scope of offshore transmission to ensure that the review of the GBSQSS adequately covers the assets which are likely to be part of an offshore transmission system. As noted in Assumption 8 in Appendix 6, the offshore transmission system considered for this assessment is illustrated below. Consideration of designs for proposed offshore wind farm developments currently in the planning process have informed a working assumption that offshore transmission systems will be radial connections to an onshore system (transmission or distribution).



**Figure 1:** Designation of offshore transmission system

23. Figure 1 shows this type of radial connection and the two interface points for a radial offshore transmission system, the Onshore Grid Entry Point (or Onshore User System Entry Point) and Offshore Grid Entry Point.
24. Figure 2 shows an example of the expected connection arrangements at an offshore high voltage platform. Four options for the Offshore Grid Entry Point were considered. These options took account of both existing arrangements in Great Britain and current proposals for offshore generation projects that are being developed. A full assessment of the options has been carried out and can be seen in annexe 1. The sub-group consider the preferred option shown in figure 2 to be the most appropriate default Offshore Grid Entry Point because this option;
  - a) best facilitates competition in generation
  - b) simplifies ownership of offshore platform assets
  - c) allows the offshore TO to provide Users with a consistent level of security; and

- d) is deemed to be consistent (if more than one party is connected) with the default boundary arrangements defined in the CUSC and STC.
- 25. The GBSQSS sub-group has assumed that the default Offshore Grid Entry Point will be at the disconnecter on the busbar side of the circuit breaker on the outgoing wind farm circuits on the offshore platform as part of its analysis work.
- 26. It has been noted that as offshore transmission will be 132kV and above in England and Wales, there will be a number of cases where the offshore transmission network will be connect to a DNO network. This issue has been highlighted by the GBSQSS subgroup who recommend that this be considered by OTEG outside the scope of the GBSQSS review.



**Figure 2: Options for Offshore Grid Entry Points**

**Assumptions made**

- 27. The recommendations reached by the sub-group take into account a number of assumptions which can be seen in full in the assumptions register in appendix 6. The key assumptions that have been made are;
  - a) offshore transmission is classed as 132kV and above
  - b) offshore transmission networks will be radial connections to the onshore electricity network
  - c) the work carried out by the sub-group will consider the connection of wind generation only to offshore electricity transmission networks
  - d) values used for MTTR assume replacement transformers are available for a failed unit
  - e) Grid Code conditions will require review, however are outside of the scope of the GBSQSS review. This review of the Grid Code will need to take account of the recommendations and assumptions made by the GBSQSS sub-group

- f) no consideration has been given to the financial compensation arrangements for loss of transmission system access or the relevant offshore transmission charging arrangements
- g) no consideration has been given to the security of connection on the distribution network should offshore transmission network connect to the DNO network.

### **Uncertainties / Risks**

- 28. In the UK there is no future guaranteed value of Renewable Obligation Certificates ('ROCs'), therefore a range of values has been considered in the cost benefit analysis.
- 29. The technology currently available for offshore generation / transmission projects has generally been designed specifically for the individual project, therefore there is limited data available for use in the analysis. Given the expected technology advances along with possible reductions in costs as the scale of offshore investment increases, the output of this cost benefit analysis is subject to potential change should the cost of installing offshore transmission assets change *substantially* from those installed.
- 30. The cost benefit analysis has tested parameters that would have a significant impact on the outcome of the analysis, an illustration of this can be seen in annexe 4, the cost benefit analysis summary report.
- 31. The analysis that has been carried out to date has assumed the connection of wind generation. The connection of other forms of generation would therefore require an additional review of the GBSQSS at a later date.

### **Offshore transmission voltage requirements**

- 32. Consideration has been given to existing onshore arrangements along with other potential options for voltage requirements for offshore transmission networks, a full report can be seen in annexe 2.
- 33. It is recommended that voltage limits will apply at the offshore platform and as a starting point these should be considered to be the same as those currently applied for onshore transmission. The sub-group however recommend these limits should be reviewed to ensure they are optimised for the application to offshore transmission networks. At the interface between the offshore TO and the onshore electricity network, Grid Code requirements currently placed on offshore generators should be duplicated in the GBSQSS for offshore networks to reflect the reactive power transfer and voltage control requirements placed upon an offshore TO.

### **Analysis results**

- 34. It should be noted that the cost benefit analysis has been based upon finding the overall optimum technical and economic solution. This has taken account of the costs and benefits of an offshore transmission system.
- 35. The cost benefit analysis has assumed a dataset as agreed by the sub-group. The values within the data set have been tested to find the boundary level that they would have to reach, in order to change the output of the analysis.
- 36. The analysis has taken account of wind farms up to 1500MW capacity and ranging between 25km to 100km from the onshore electricity grid connection point. The appropriate HV and LV switching arrangements have not been considered.
- 37. On the basis of the results of the cost benefit analysis, the security for offshore transmission networks can be assessed in two sections; the offshore platform (including AC transformers and DC converters), and the cable network (between the offshore platform and the relevant onshore network). The main recommendations reached are shown in the recommendations section below.

38. The cost benefit analysis has concluded that for wind farms with an export capacity of 120MW or greater, it is more economical to install greater than the minimum number of AC platform circuits in order to meet required wind farm export capacity. i.e. two 60MW transformers / interconnecting circuits are more economical than one 120MW transformer / interconnecting circuit.
39. Due to the dispersed location of offshore wind generators, statistically there is a low probability that full output of all individual wind generators will be available at any given time. It has been noted that the individual user would be in the best position to determine that level and hence the transmission entry capacity requested in the case of a single connection. In the case of multiple user connections, the offshore TO would have to determine the level of system capacity required. The cost benefit analysis has concluded that for the connection of multiple wind farms, the offshore network capacity should be planned to 90% of the cumulative installed capacity of the wind farms connected due to the cost of installing offshore transmission assets to the full capacity. In cases where this value requires marginal additional assets to be installed, consideration should be given to installation of network capacity below 90% if it can be justified to be economic and efficient. Guidance on this process should be provided in an appendix to the security standards.

### ***Sensitivity assessment***

40. A number of key items of the input data to the cost benefit analysis have been tested to determine at what level they would change the outcome of the cost benefit analysis. A full list of the sensitivities considered can be seen within appendix 4 – the cost benefit analysis data set. A summarised report detailing the output of the cost benefit analysis can be seen in annexe 4, this document illustrates a number of the values that have been tested.

### **GBSQSS Sub-group Recommendation for criteria for the new Standard**

41. In making these recommendations it should be noted that these apply to both the planning and operation of offshore transmission networks.
42. Based on the result of this analysis, it is considered that the onshore GBSQSS planning and operational standards are not appropriate for application to offshore transmission network development due to the relative cost and available ratings of offshore transmission assets that would be required to be installed for compliant network designs.
43. The cost benefit analysis was undertaken on the basis that the security standard should not be technology specific. The conclusion to the analysis is that, to ensure clarity, the standard could be written differently for the use of AC and DC technology at the offshore platform.
44. It should be noted that offshore wind farms proposing to connect using HVDC are likely to make use of voltage-source converter (VSC) technology. There is no reliability and cost data available for converters in excess of 1000MW, therefore it is not possible to assess the use of converters for single module connections above this value of 1000MW. It is therefore considered prudent to limit the largest connection to a single converter module at the existing onshore Normal Infeed Loss Risk (1000MW). Based on predicted estimates of failure rate provided by manufactures, analysis suggests that the loss of power infeed resulting from a single converter module could be above this value, however this should be assessed once the technology is available.

45. It is recommended that for multiple wind farm connections, the offshore network capacity is planned to accept 90% of the installed capacity of wind farms connected, due to the cost of installing offshore transmission assets to full capacity. In all cases where this value requires marginal additional assets to be installed, consideration should be given to installation of network capacity below 90% if it can be justified to be economic and efficient. Guidance on this process should be provided in an appendix to the security standards.
46. It should be noted that this recommendation states an alternative provision of transmission system capacity for single and multiple wind farm connections. This recommendation assumes a single wind farm connection as a single user, whereas multiple wind farm connections are considered as multiple users. It should be further noted that an unintended consequence of this recommendation is that there are a number of cases where benefits could be seen in connecting multiple wind farms as opposed to a single wind farm. The contractual structures in the recommendation have the potential to be exploited.
47. The recommendation for offshore GBSQSS is that the security assessment for offshore transmission networks can be considered in three sections;
  - a) Offshore platform (AC transformers, AC platform interconnection circuits and DC converters)
    - i) AC platforms should be designed such that the High Voltage and Low Voltage terminals of the platform circuits are interconnected to allow for full flexibility of use of all assets housed upon it.
    - ii) For single wind farm connections:

Platform capacity should be planned to accept the export capacity of the wind farm with no equipment loadings exceeding their pre-fault rating.

For AC platform designs; for wind farms with an export capacity of 120MW or greater, following the outage (planned or unplanned) of a single offshore platform AC transmission circuit, the reduction in platform export capacity should not exceed 50% of installed platform capacity. For the avoidance of doubt, this should not exceed 1000MW.

For DC platform designs; Platform capacity should be planned such that following the outage (planned or unplanned) of a single offshore platform DC converter module, the loss of power infeed shall not exceed existing onshore Normal Infeed Loss Risk (1000MW<sup>6</sup>).
    - iii) For multiple wind farm connections:

Platform capacity should be planned to accept 90% of the cumulative installed capacity of the wind farms connected, with no equipment loadings exceeding their pre-fault rating.

For AC platform designs; for wind farms with a cumulative installed capacity of 120MW or above, following the outage (planned or unplanned) of a single offshore platform AC transmission circuit, the reduction in platform export capacity should not exceed 50% of the installed platform capacity. For the avoidance of doubt, this should not exceed 1000MW.

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<sup>6</sup> HVDC converter technology is not available for modules above 1000MW, therefore reliability and cost data was not available to assess this limit. Analysis has indicated that subject to the availability and reliability of larger converters it may be possible to increase this limit



For DC platform designs; Platform capacity should be planned such that following the outage (planned or unplanned) of a single offshore platform DC converter module, the loss of power infeed shall not exceed existing onshore Normal Infeed Loss Risk (1000MW).

- iv) Following the unplanned outage of a single offshore transmission platform circuit during the planned outage of an offshore transmission platform circuit, the reduction in platform capacity should not exceed 1320MW.
- b) Offshore network capacity (AC / DC cables)
- i) For single wind farm connections the transmission cable circuit capacity should be planned to accept the export capacity of the wind farm with no equipment loadings exceeding the pre-fault rating.
  - ii) For multiple wind farm connections the transmission cable circuit capacity should be planned to accept 90% of the cumulative installed capacity of the wind farms connected to it, with no equipment loadings exceeding their pre-fault rating
  - iii) Following the outage of a single offshore transmission cable circuit, the reduction in cable circuit capacity should not exceed 1500MW. This value is bounded by the limit in scope of the cost benefit analysis. i.e. can allow up to 1500MW to be connected to a single transmission cable circuit.
  - iv) Following the unplanned outage of a single offshore transmission cable circuit during the planned outage of an offshore transmission cable circuit, the reduction in circuit capacity should not exceed 1500MW. This value is bounded by the limit in scope of the cost benefit analysis
- c) Voltage requirements
- i) Voltage requirements for offshore networks should include the interface with the onshore network, particularly with respect to reactive power transfer. It is recommended that the existing Grid Code obligations CC.6.3.2(b), CC.6.3.2(c) and CC.6.3.8(c) on generators, at the point of connection, be adopted at the connection point of an offshore transmission network to an onshore system. Note that studies to inform this issue are ongoing.
  - ii) Steady-state operational and planning voltage limits based on the existing limits for onshore transmission networks should be adopted. However, the nominal voltages will have to be adapted to cover a wider range of voltages.
  - iii) Engineering Recommendation P28 compliance should not be required in an offshore network except at the point of connection with the onshore network. For secured events voltage fall should not exceed -6% (may be relaxed to -12% for certain major events) and voltage rise should not exceed +6%. For operational switching at intervals of less than 10 minutes, a maximum voltage fall of -6% is allowable. Note that, due to the possible impact on equipment, consultation with manufacturers on offshore voltage-step limits is ongoing.

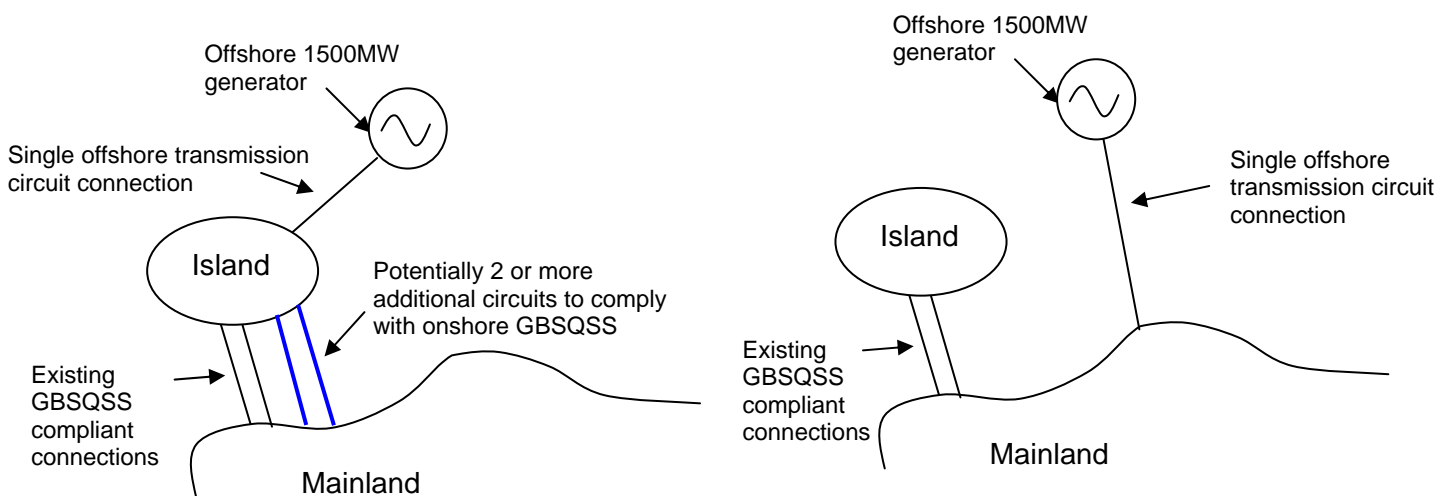
48. It is recommended that the voltage requirements for offshore transmission networks at the connection to onshore networks should be contained within the security standards for offshore transmission networks. This recommendation is in line with existing arrangements. It is recommended that the Grid Code sub-group of OTEG takes account of this recommendation in their assessment of Grid Code requirements for offshore wind farms connecting to offshore transmission networks<sup>7</sup>.
49. In line with the existing GBSQSS, it is recommended that the offshore transmission security standards allow the transmission licensee to meet a Generator's request for security above or below the minimum planning standard provided there is no adverse impact on any other user.
50. It should be noted that due to the expected radial nature of connections to the onshore network, there could be large volumes of generation connected via a single offshore transmission circuit, resulting in a risk to the generator and / or offshore transmission SO. The consequential impact of this recommendation on the access rights, compensation arrangements and transmission charging for offshore generation is outside the scope of the sub-group work and has therefore not been considered.
51. It should be noted within the standard that for the connection of demand to the offshore transmission network, a review will be required of the security of connection to be provided. At the time of writing this recommendation, it is not envisaged that there will be any demand connections in the foreseeable future.
52. It should be noted that if the offshore transmission system is operated in parallel with the onshore transmission network then the MITS standards will apply to the relevant section of offshore transmission network.
53. A full review of the GBSQSS Terms and Definitions will be required as part of the drafting required implementing this recommendation in the GB SQSS.
54. Given the results of the cost benefit analysis have shown that in certain cases there would be a requirement to consider the use of alternative technologies further, it is recommended that the existing GBSQSS appendix dealing with cost benefit analysis be extended to include consideration of offshore networks.
55. It should be noted that the existing GBSQSS appendices should be reviewed at the same time as the drafting of the GBSQSS wording for the inclusion of offshore transmission networks to ensure consistency with existing standards.

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<sup>7</sup> It has been assumed that Grid Code requirements on offshore wind farms will apply at the point of connection to the offshore network and no longer at the connection point to the onshore transmission network. This change to the point of application of the requirements may also necessitate a change to the detailed Grid Code requirements that would apply specifically to offshore wind farms; it is therefore recommended that these be reviewed.

### Issues and further work for OTEG consideration

56. The GBSQSS sub-group identified the following issues for consideration by OTEG:
- a) In Great Britain there are no obligations on a DNO to provide secure access rights to embedded generation. In the case of an offshore transmission network connecting to a DNO network, the offshore transmission network will be designed to meet the minimum planning standards defined in the GBSQSS, however the DNO network it is connecting to will limit the access available to the offshore generator. This causes both contractual interface issues as well as technical issues, as the design of a transmission network offshore may be un-economic if the on-shore network is unable to deliver the power to the end consumer. Although not considered by the sub-group, DNO access rights are a major commercial consideration for users of the offshore transmission network. This issue has been highlighted by the GBSQSS subgroup, and recommend that this be considered by OTEG outside the scope of the GBSQSS review.
  - b) The Grid Code review will need to take account of recommendations and assumptions made by the GBSQSS sub-group.
  - c) The consequential impact of this recommendation on the access rights, compensation arrangements and transmission charges for offshore generation should be considered.
  - d) Note the unintended consequence of this recommendation whereby the contractual structures in the recommendation have the potential to be exploited when connecting single and multiple users.
57. The GBSQSS sub-group identified the following further work to be considered during November 2006
- a) The security requirements for demand connected to offshore transmission networks.
  - b) The security requirements for offshore networks connecting generating plant with a higher annual capacity factor (e.g. offshore CCGT, tidal etc).
  - c) The impact that this recommendation will have on the connection of generation where geographically proximate to any island off mainland England, Wales and Scotland. In line with the recommendation presented, in this case the connection of offshore generation could require different levels of capital investment where the offshore generation connects to the island or connects straight to the mainland, as illustrated in figure 3



**Figure 3:** Connection of generation geographically proximate to an island off

*mainland England, Wales or Scotland*

58. The GBSQSS sub-group identified the following further work to be considered with timescales to be advised by OTEG.
- a) The GBSQSS sub-group have provided a recommendation on the voltage requirements for offshore transmission, the specific voltage limits have not been considered. This will be required prior to the drafting of the standard to include offshore transmission.
  - b) Feed into, if requested, discussions on Embedded Transmission
  - c) Feed into, if requested, discussions on access rights and compensation arrangements
  - d) In a limited number of cases it could be more economical to install Low Voltage (LV) interconnection between offshore transmission platforms to avoid installation of additional transformers. The ownership of these circuits at voltages below 132kV should be considered.