Appendix 1
Terms of Reference of the GB SQSS sub-group of OTEG

Terms of reference for the GB SQSS sub group of OTEG

Background

The Ofgem scoping document published in April 2006 identified the issues that require further consideration in implementing an offshore electricity transmission regime. One of the identified work streams was the need to review the existing technical rules governing onshore networks to see how they could be made to work offshore.

At the first meeting of OTEG on 4 May 2006 it was decided to establish a sub group ('the GB SQSS sub group') to undertake review work to assist Ofgem/DTI decisions relating to offshore transmission system security requirements. The GB SQSS sub group will report to OTEG who will oversee the progress of this specialist sub group. OTEG will also provide a single point of contact to address any issues that arise from the GB SQSS sub group discussions.

Composition of the sub group

OTEG is of the view that the GB SQSS sub group requires a focussed membership reflecting the complex technical nature of the issues that the sub group will be required to consider. Accordingly, membership of the GB SQSS sub group will be limited to representatives from parties who had direct involvement in the development of the recent process under BETTA to harmonise onshore GB SQSS and parties who are, or will soon be, directly and significantly involved and experienced in the development of imminent offshore transmission networks.

The GB SQSS sub group is proposed to comprise of the three transmission licensees (NGET is expected to provide representation of its GBSO and its TO interests) and those offshore developers who at present have received offers for connection to onshore networks.

OTEG will have the right to invite other representatives (e.g. distribution licensees, offshore transmission equipment manufacturers) should the GB SQSS sub group consider that such expert knowledge is required.

The number of representatives from each party will be limited to one (other than NGET who will be limited to one representative of its GBSO activity and one representative of its TO activity). Each representative will be able to invite an additional technical advisor to sub group meetings as required. The chair of this sub group will be appointed by OTEG. The sub group at their first meeting will be required to appoint a secretary. It is recommended that these roles are filled by industry representatives.

Representatives from Ofgem and DTI will also be invited to the sub group meetings. The frequency, timing and location of the meetings will be agreed at the first meeting.

Purpose

The GB SQSS sub group is an advisory body, not a decision making body. The purpose of the group is to assist OTEG by completing a review of the current GB SQSS and consequently considering:-

- whether it is appropriate to apply to the present onshore standard to offshore transmission networks
- if amendments are needed to extend the GB SQSS offshore; and
- the range of options that exist for alternative security standards for offshore transmission networks.

Participation

Participants at any sub group acknowledge and agree that any draft text disclosed to them is confidential and must not be disclosed to any other person, business or undertaking other than the participants in the sub group meeting, their employees directly involved with this work and their advisors directly involved with this work or as the participants in the sub group may agree.

While the active participation of participants in any sub group is sought with the evaluation of technical rules, all participants acknowledge and agree that Ofgem/DTI are ultimately responsible for determining the form and content of the security standards relating to offshore transmission networks and any discussion in meetings and views expressed or implied in such discussion or document are entirely without prejudice to and shall not limit the discretion of Ofgem/DTI with regard to the final form and content of the document.

The participants also acknowledge and agree that the participation (including any discussion in meetings and views expressed or implied in such discussion or papers) in meetings, is entirely without prejudice and shall not limit the discretion of the licensees to comment during any future consultation of any Ofgem/DTI proposals published concerning the security standards relating to offshore transmission networks.

Deliverables

The GB SQSS sub group will be required to provide:

- a report to OTEG detailing the sub group's review of the current GB SQSS identifying any issues associated with its application offshore
- recommendations to OTEG identifying feasible options for security standards relating to offshore transmission networks, the rationale supporting potential options and the views of the subgroup on each option; and
- responses to technical queries as referred by OTEG.

Objectives

Ofgem/DTI's initial stance is that there may be merit for a single set of standards to apply across the whole of GB and within relevant offshore areas, since this:

- builds on the harmonised arrangements delivered as part of BETTA;
- ensures consistency between onshore and offshore transmission arrangements

However the options presented by the subgroup will need to consider whether there are justifiable and workable alternatives to this.

The specific objectives of the GB SQSS sub group are as follows:

a) Develop a framework of security rules that can be applied to offshore transmission networks that is compatible and consistent with the current onshore transmission network and market structure
b) To achieve (a) it will be necessary to assess the relevance of the existing GB SQSS for offshore transmission networks in the first instance and, if required, to outline any amendments that are needed to extend the GB SQSS offshore
c) Identify and develop a range of feasible alternative options for security standards relating to offshore transmission networks.

In achieving the above objectives the GB SQSS sub group will need to take account of the need (these are listed in no particular weighting or order):

- for existing transmission licensees to meet existing SQSS compliance requirements in respect of the onshore transmission network;
- to minimise the overall level of transmission costs;
- to ensure the safe operation of all transmission circuits;

- to clearly and robustly define all aspects of the security rules framework to minimise the risk of misinterpretation when applying rules relevant to planning and operating of transmission networks;
- for no undue discrimination on a geographic basis;
- to ensure consistency and compatibility with onshore market and industry structure, and
- to promote equality of treatment in respect of system access for transmission users across GB.

The review work requested of the GB SQSS sub group:

- does not constitute a fundamental review of the need for the existing criteria within the GB SQSS in respect of the onshore transmission network;
- should not result in any need for significant additional investment in the onshore transmission network;
- should not result in any unjustified costs for offshore transmission networks.
- should not lead to any significant change to the existing security and quality of supply delivered to onshore transmission customers;
- should not result in a significant increase in the system operation costs associated with the onshore transmission network, and
- should not have an impact on the current transmission pricing methodology.

Accountability

The sub group will report to OTEG. The chair of the sub group is required to provide regular reports to OTEG and ensure that work is progressed by the sub group in accordance with OTEG's instructions.

Appendix 2

GBSQSS sub-group members

Edgar Goddard (Chair)	National Grid
Jonathan Davies (Secretary)	National Grid
Andy Hiorns	National Grid
Bridget Morgan	Ofgem
Anthony Mungall	Ofgem
Philip Baker	DTI
Cornel Brozio	SPT
Chandra Trikha	SSE
Robert Longden	Airtricity
Matthew Knight	BEAMA
Joe Duddy	RES
Goran Strbac	SEDG Centre
Paul Newton	E.ON (part)
Claire Maxim	E.ON (part)

Appendix 3

The present GBSQSS standard

1. At present, all of the security criteria to be applied when planning and operating the transmission system are contained in one document. The following is a summary of the document contents and the chapters that the GBSQSS sub-group considers would need to be changed to accommodate offshore transmission systems within the GBSQSS:

   Chapter 1 – Introduction
   Chapter 2 – Design of Generation Connections
   Chapter 3 – Design of Demand Connections
   Chapter 4 – Design of the Main Interconnected Transmission System (MITS)
   Chapter 5 – Operation of the GB transmission system
   Chapter 6 – Voltage limits in planning and operating the GB transmission system
   Chapter 7 – Terms and Definitions
   Appendices A-E

2. Chapter1 presents the role, scope and structure of the GBSQSS. This chapter will require amendment to reflect the additional section/s added upon the inclusion of offshore transmission networks standards into the GBSQSS

3. Chapter 2 presents the deterministic criteria by which all generation connections to the GB transmission system should be connected. Within this chapter, the main points to note are;

   a) For the loss of a single transmission circuit, no loss of power infeed shall occur
   b) For the loss of a single generation circuit or busbar, the loss of power infeed shall not exceed 1000MW
   c) For the loss of a single circuit while one is on arranged outage the loss of power infeed shall not exceed 1320MW

4. As noted in assumption A03, it is assumed that all offshore transmission networks will be radial connections, therefore chapter 2 will have greatest impact on the security level employed for offshore transmission.

5. Chapters 3 and 4 presents the deterministic rules for the security of connection of demand and design MITS respectively. It has been assumed that there will be no demand connected to the offshore transmission networks, along with the connections being radial, therefore these chapters not been reviewed.

6. It is recognised that should the offshore transmission network parallel the onshore transmission system then the onshore MITS standards should apply to the offshore transmission network.

7. Chapter 5 details the operational criteria that must be met during the operation of the GB transmission system. The recommendations seen in this paper apply to both the planning and operation of the GB transmission system

8. Chapter 6 presents the voltage limits to be met during the planning and operation of the GB transmission system. A full review of these limits has been carried out and can be seen in annexe 2.

9. Chapter 7 states the Terms and Definitions as used throughout the GBSQSS. It is noted that there are a number of items that may require review. Revised text will follow the GBSQSS consultation in late October 2006.

10. The appendices to the GBSQSS provide supporting information to the main chapters. With the introduction of an additional section for the planning and operation of Offshore transmission networks there will be a requirement to review these to ensure their relevance to offshore application, as well as the possibility of introducing an additional appendix to highlight the methodology undertaken during the cost benefit analysis work.

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Appendix 4

Cost benefit analysis dataset

Source of data seen in italic

<u>Offshore windfarm</u>

Size and distance of offshore wind farm

Up to 1500MW wind farm *(agreed by the GBSQSS sub-group)*
Up to 100km distance from shore *(agreed by the GBSQSS sub-group)*

Generator

Availability 95% *(BEAMA and developers)*

Sensitivity studies: 90%-100%

Value of curtailed energy and losses

Cost of energy for evaluation of costs of losses and cost of expected energy curtailed:
75£/MWh. Evaluation of capitalised costs of energy: discount rate 8%, period 25 years. *(agreed by the GBSQSS sub-group)*

Sensitivity studies: low value 50£/MWh, high value 100£/MWh

Wind resource

Load factor 40%. Two profiles: (i) diversified and (ii) non-diversified across the installed windfarm

Alternative distribution - Weibull parameters c=10, k=2 *(Airtricity)*

<u>AC transmission (transformers and compensation)</u>

Transformers

Reliability

Failure rate: 0.03 failures per year *(Developers)*
Repair time: 4.5 months *(Developers)*

Sensitivity studies: low value 3 months, high value 6 months

Electrical parameters

Load losses 0.6% *(Developers)*
No-load losses 0.03% *(Developers)*
Reactance: 15% *(Developers)*

Costs of transformers + associated equipment

£25/kVA (for two transformers on a platform) *(BEAMA)*
20% additional cost for third and each successive transformer *(BEAMA)*
20% decrease in cost for just one transformer on a platform *(BEAMA)*

Cost of platform

£5m per transformer plus *(BEAMA)*
20 £/KVA (for topside structures) *(BEAMA)*
Assumes 2 transformers, add 20% structure cost for each additional transformer *(BEAMA)*

Transformer repair costs

£2.5m / repair *(BEAMA)*

Cost of compensation

Offshore £25/kVAr *(BEAMA)*
Onshore £15/KVar *(BEAMA)*

LV switchgear

Unavailability: ignored *(BEAMA)*

Full flexibility assumed

Maintenance requirements: Visual inspection 2 yrs, grease mechanism 5 years, check gas 10 years. No significant invasive work required for the 25 year lifetime of a typical windfarm. i.e maintenance ignored for this analysis. *(BEAMA)*

Mean time to repair: Best case 5 days, worst case 1 month. (BEAMA)

Fault level constraints of switchgear: Standard breaker 31.5kA, 40kA available for little increase in capital cost. (BEAMA)

Capital cost: incorporated in transformer cost

HV switchgear

Unavailability: ignored (*BEAMA)*

Full flexibility assumed

CABLES

Electrical Parameters of AC 132kV and 220kV offshore cables *(ABB)*

Nominal Voltage		132 kV				220 kV			
		500mm^2	630mm^2	800mm^2	1000mm^2	500mm^2	630mm^2	800mm^2	1000mm^2
Max continuous load	**MVA**	**169**	**187**	**203**	**217**	**279**	**308**	**335**	**359**
Conductor a.c resistance at max. temperature, R_{ac}	Ω/km	0,0493	0,0395	0,0324	0,0275	0,0489	0,0391	0,0319	0,0270
Cable a.c resistance at max. temperature, R_{ac}	Ω/km	0,0631	0,0537	0,0471	0,0431	0,0660	0,0564	0,0494	0,0448
Conductor losses per phase at 100 % load	W/m	26,86	26,34	25,66	24,76	26,19	25,47	24,71	23,92
Screen/sheath losses per phase at 100 % load	W/m	5,17	6,58	8,40	9,98	6,26	7,74	9,56	11,37
Armour losses per phase at 100 % load	W/m	2,42	2,88	3,24	4,01	2,86	3,55	3,98	4,42
Dielectric losses per phase, W_d at nominal voltage	W/m	0,140	0,153	0,158	0,173	0,276	0,306	0,330	0,359
Total losses per phase at 100 % load & nom. Voltage	W/m	34,59	35,95	37,46	38,93	35,59	37,07	38,58	40,07
Conductor temperature at 75 % load	°C	52,1	53,9	54,6	55,2	53,6	54,1	[illegible]	55,3
Total losses p[illegible]	[illegible]	18,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22,5
Conductor ten[illegible]	[illegible]	29,8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31,4
Total losses pe[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10,2
Conductor temperature at 25 % load	[illegible]	16,5	16,7	16,9	17,0	16,8	17,0	17,2	17,3
Total losses per phase at 25 % load	W/m	2,0	2,2	2,4	2,5	2,3	2,5	2,6	2,8
Capacitance, per phase	µF/km	0,192	0,209	0,217	0,238	0,136	0,151	0,163	0,177
Capacitive charging current, per phase at nominal voltage	A/km	4,589	5,005	5,196	5,689	5,434	6,024	6,504	7,066
Capacitive load at nominal voltage & 50 km of cable	MVAr	52,5	57,2	59,4	65,0	103,5	114,8	123,9	134,6
Inductance between conductors, per phase	mH/km	0,387	0,372	0,364	0,351	0,437	0,415	0,400	0,386
Inductive reactance, (star reactance)	Ω/km	0,122	0,117	0,114	0,110	0,137	0,130	0,126	0,121

Note that all calculations are based on:		
Thermal resitance of soil / seabed	K.m/W	0,8
Temperature at burial depth	°C	12
Burial depth	m	2
Parallel heat sources		No
Soil moisture migration		No
FXBTV cable		According to design layout

"Hotspots" such as HDD at sea-defence crossings or J-tube installations should not be a sizing factor for the cable design.

"Hotspots" (at sea-defence crossings) can be avoided by using external cooling or transition joints.

"Hotspots" (at J-tube installations) can be avoided by using "open top" or fully ventilated J-tubes

Costs *(BEAMA)*

Voltage kV	X section sqmm	Supply Euro k/km	Supply GBP k/km	Lay and Bury GBP k/km	Circuit Total
3 core					
132	1000	550	390	200	590
132	800	440	310	190	500
132	500	330	240	180	420
220	800	470	440	220	660
220	500	400	390	200	590
Single core					
400	800	1200	860	540	1400

DC transmission - VSC

Converters with associated equipment (circuit breakers, transformers filters etc)

Max size of converter 500 MW *(BEAMA)*

Capital cost of converters £110/KVA *(BEAMA)*
20% additional costs for each additional converter (above 500 MVA)

Mean time to repair 1 month *(BEAMA)*

Failure rate 0.12 failures per year *(BEAMA)*

Losses per converter station *(BEAMA)*
0.8% losses at no load
0.8% losses at full load

Cost of platform £25m *(BEAMA)*

Repair costs £500k/repair *(BEAMA)*

DC Cables – capacity and resistance (ABB)

Cable data

Power per bipole MW	Climate type	Submarine Cables			Land Cables		
		Conductor copper mm²	Cable diameter mm	Cable weight kg/m	Conductor aluminium mm²	Cable diameter mm	Cable weight kg/m
		+/- 150 kV Submarine Cables			+/- 150 kV Land Cables		
460 MW	Moderate	1 800	109	40	Use Cu	90	21.0
	Tropic	2 000	112	42	Use Cu	93	22.6
320 MW	Moderate	1 000	97	29	1 400	84	7.9
	Tropic	1 200	101	31	2 000	93	10.1
140 MW	Moderate	240	69	13	400	60	3.5
	Tropic	300	71	14	500	63	4.0
		+/- 80 kV Submarine Cables			+/- 80 kV Land Cables		
70 MW	Moderate	185	52	8	300	41	2.0
	Tropic	240	54	9	400	45	2.3

Indicative only

Resistance:

Table 21

IEC				
Cross section		Diameter approx.	Maximum d.c. resistance at 20°C, ohm/km	
mm²	kcmil	mm	aluminium	copper
25	49	5.8	1.20	0.727
35	69	7.0	0.868	0.524
50	99	8.0	0.641	0.387
70	138	9.6	0.443	0.268
95	187	11.2	0.320	0.193
120	237	12.8	0.253	0.153
150	296	14.2	0.206	0.124
185	365	15.9	0.164	0.0991
240	474	18.0	0.125	0.0754
300	592	20.5	0.100	0.0601
400	789	23.1	0.0778	0.0470
500	987	26.4	0.0605	0.0366
630	1243	30.2	0.0469	0.0283
800	1579	33.9	0.0367	0.0221
1000	1973	37.9	0.0291	0.0176
1200	2368	41.4	0.0247	0.0151
1600	3158	47.4	0.0186	0.0113
2000	3947	53.5	0.0149	0.0090
2500	4934	66	0.0120	0.0072
3000	5920	72	0.0100	0.0060

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AC and DC cable parameters

Reliability

Failure rate: 0.08 failures/100km per year *(BEAMA)*
Repair time: 3 months *(BEAMA / DEVELOPERS)*

Sensitivity studies: failure rate +/- 50% failure rate

Repair costs

£500k / repair (BEAMA)

Costs of Voltage source based HVDC (BEAMA)

2 DC cables (VSC)

Voltage	X section	Supply	Supply	Lay and Bury	Circuit
kV	**sqmm**	**Euro k/km**	**GBP k/km**	**GBP k/km**	**Total**
150	*2000*		*500*	*400*	*900*

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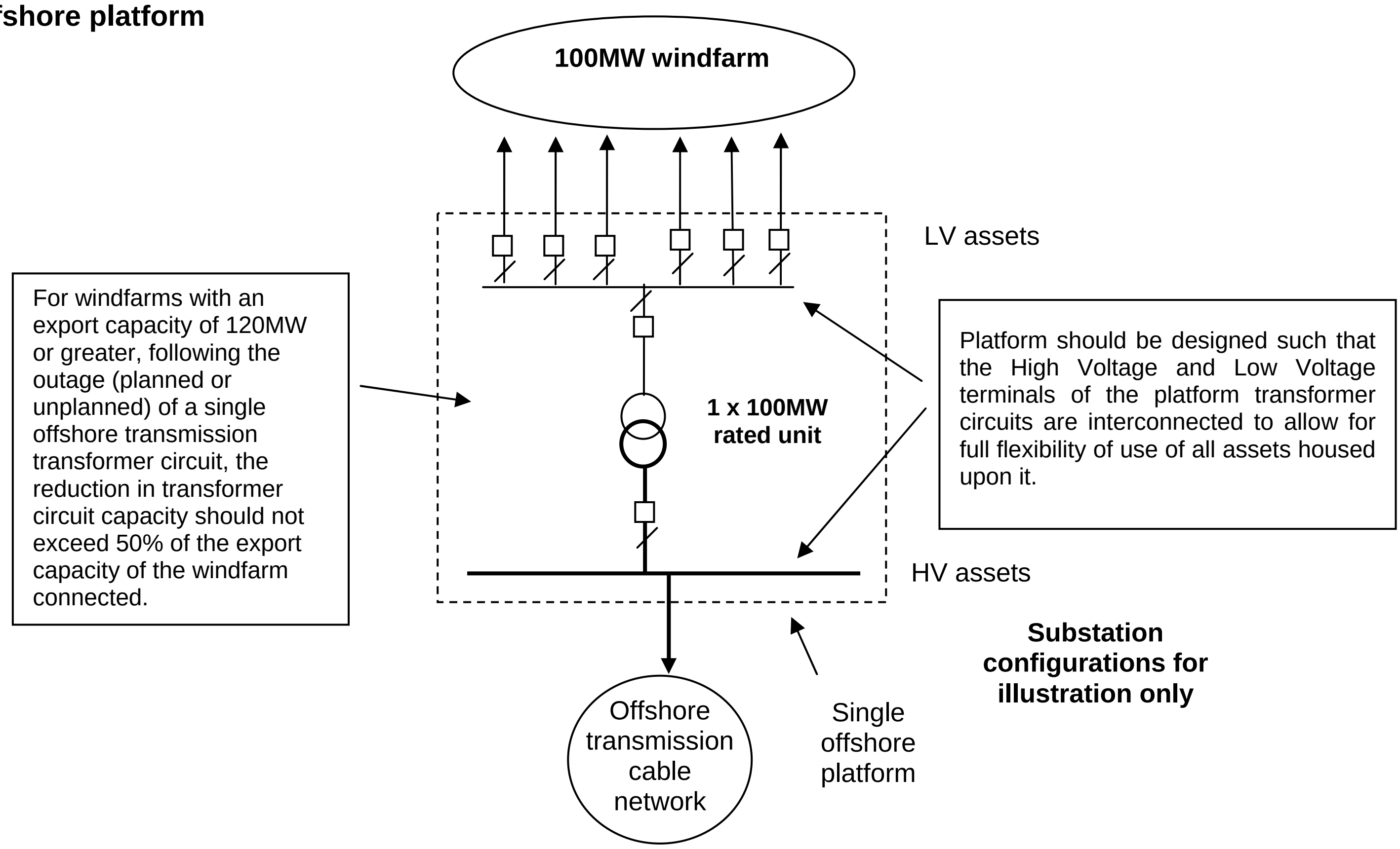
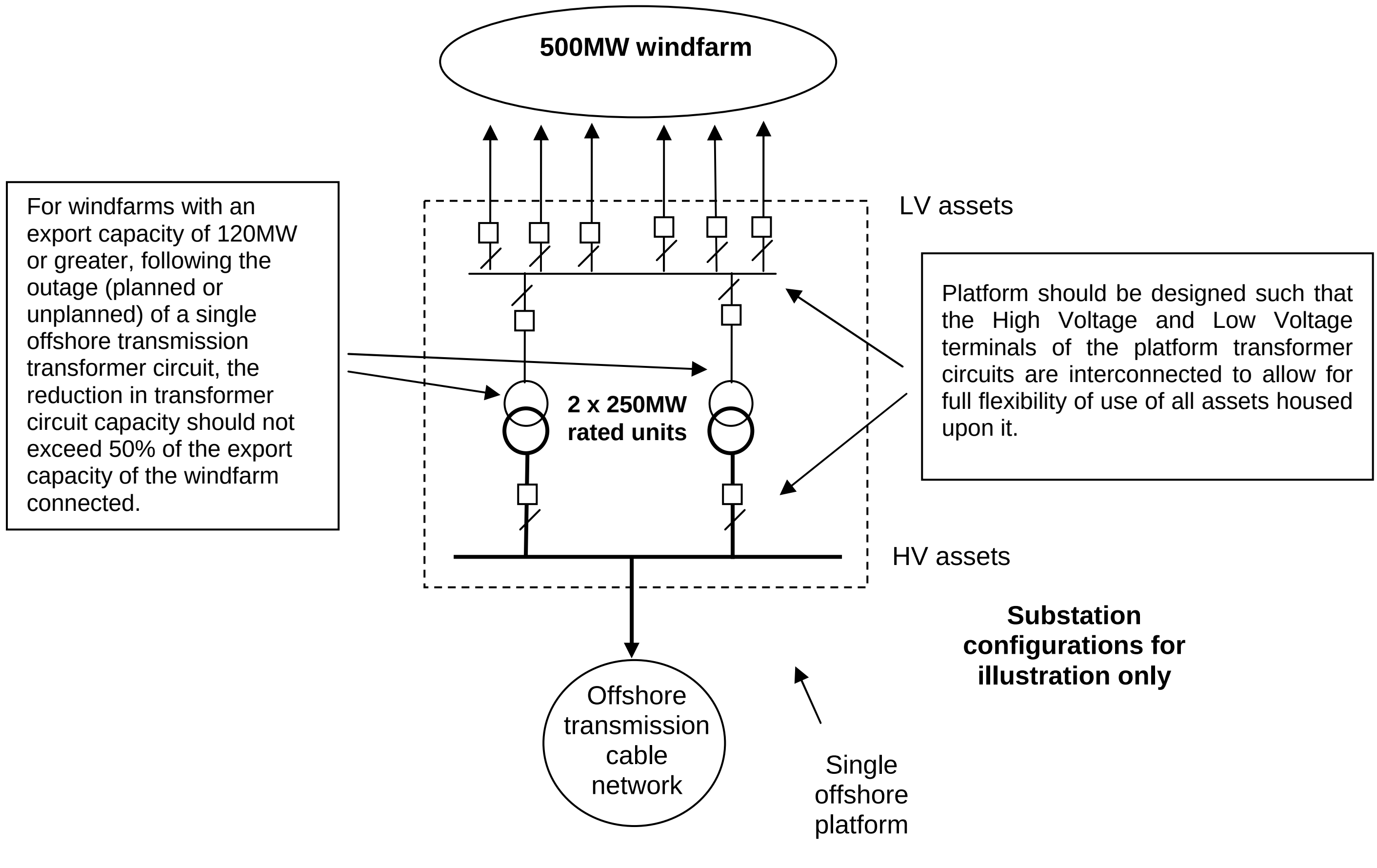
Appendix 5

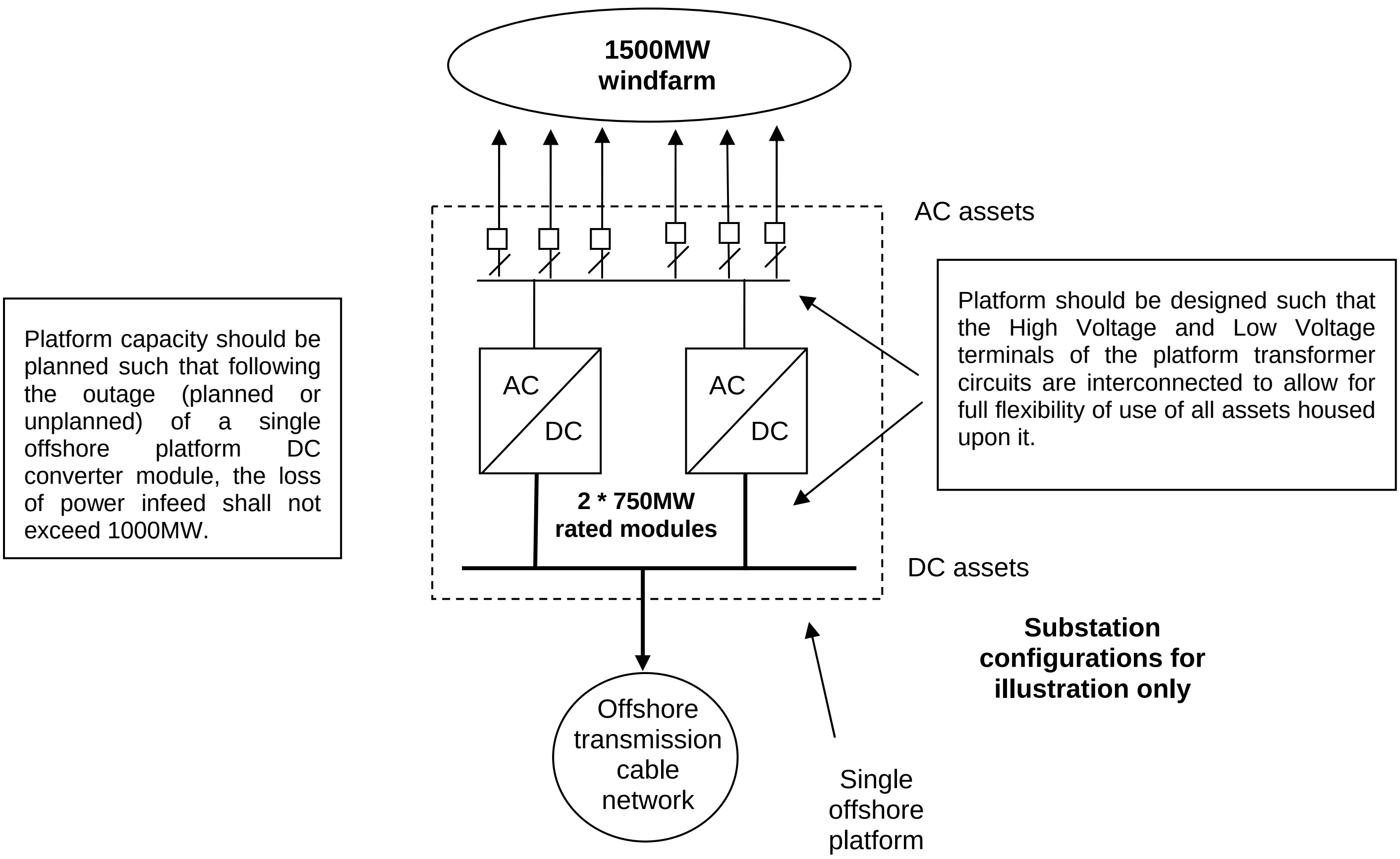
Illustration of recommendations

Single windfarm connections

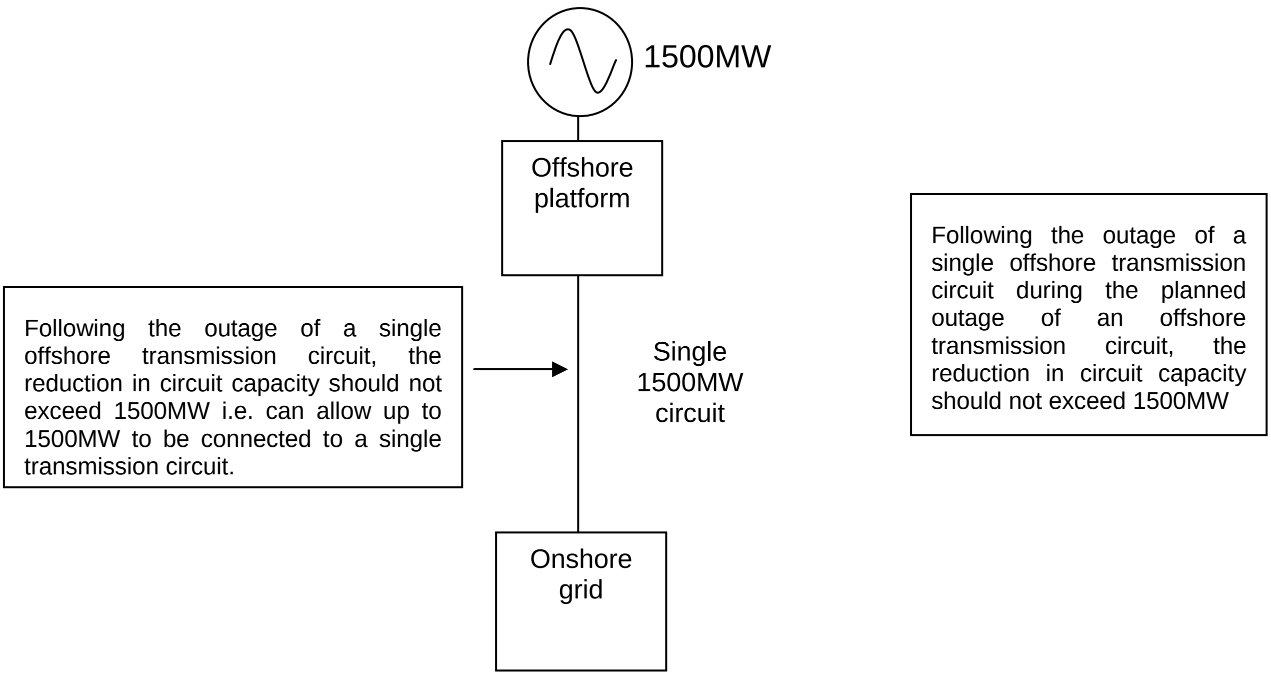
Offshore platform



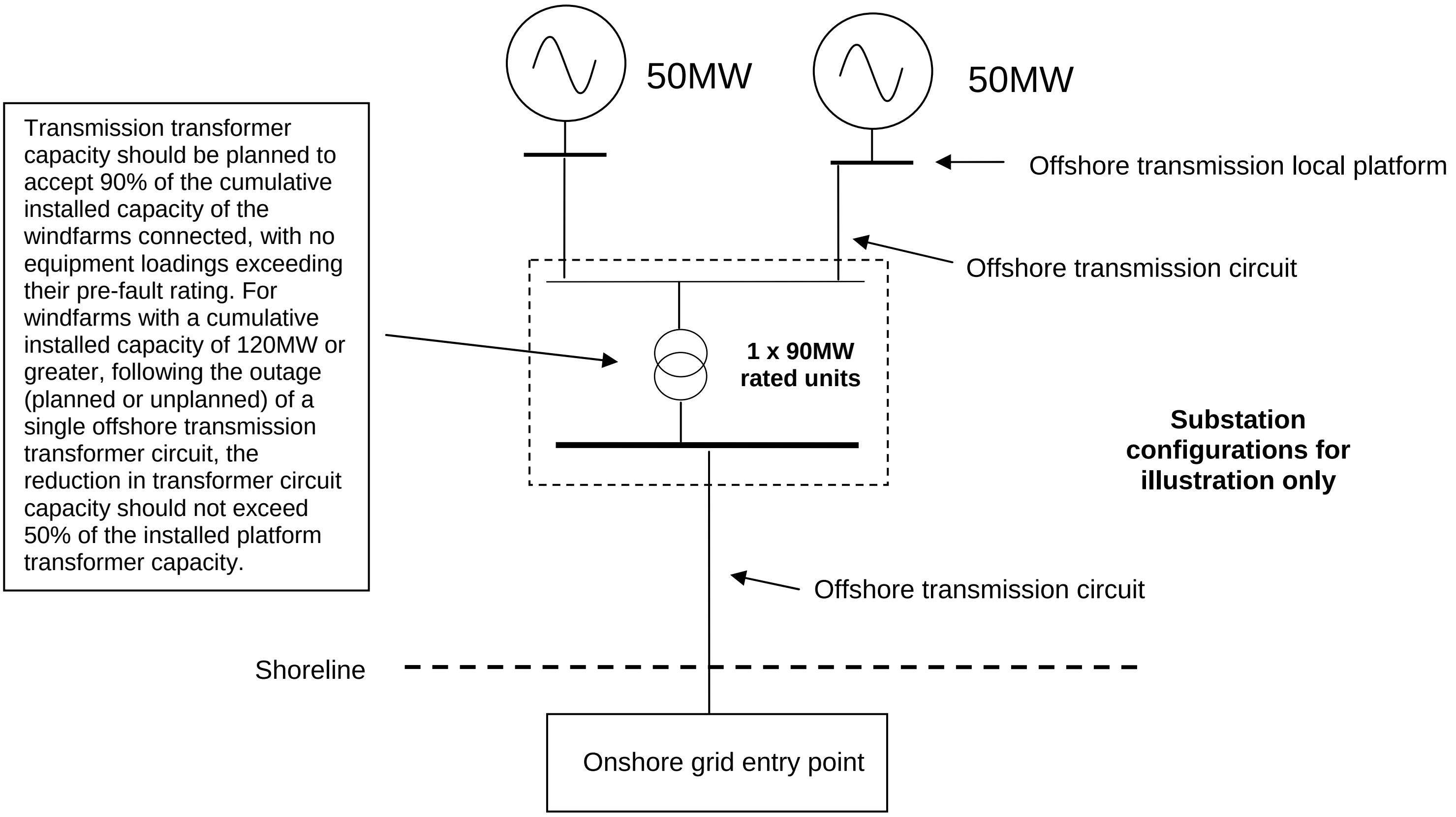


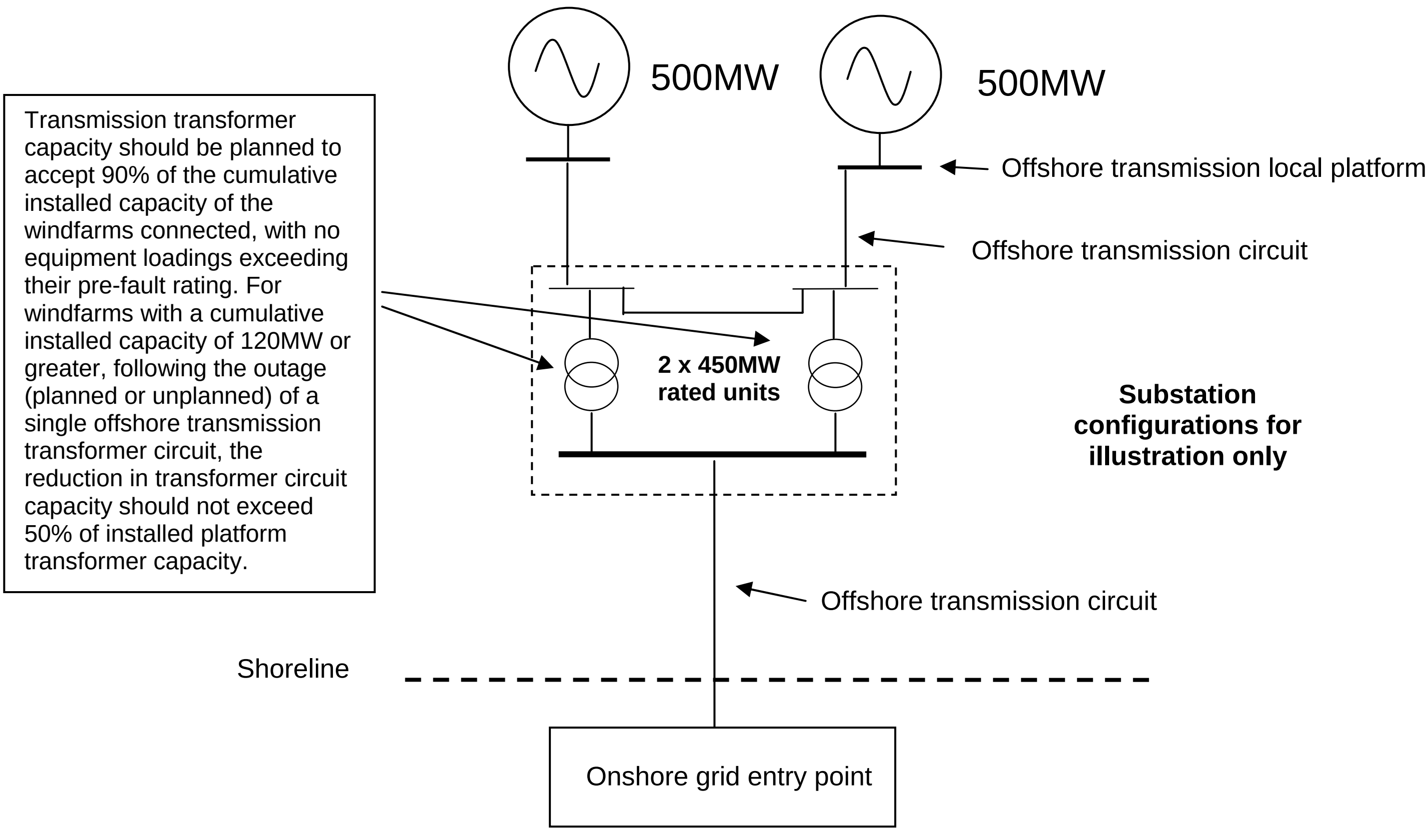


Offshore network capacity (AC and DC cables)

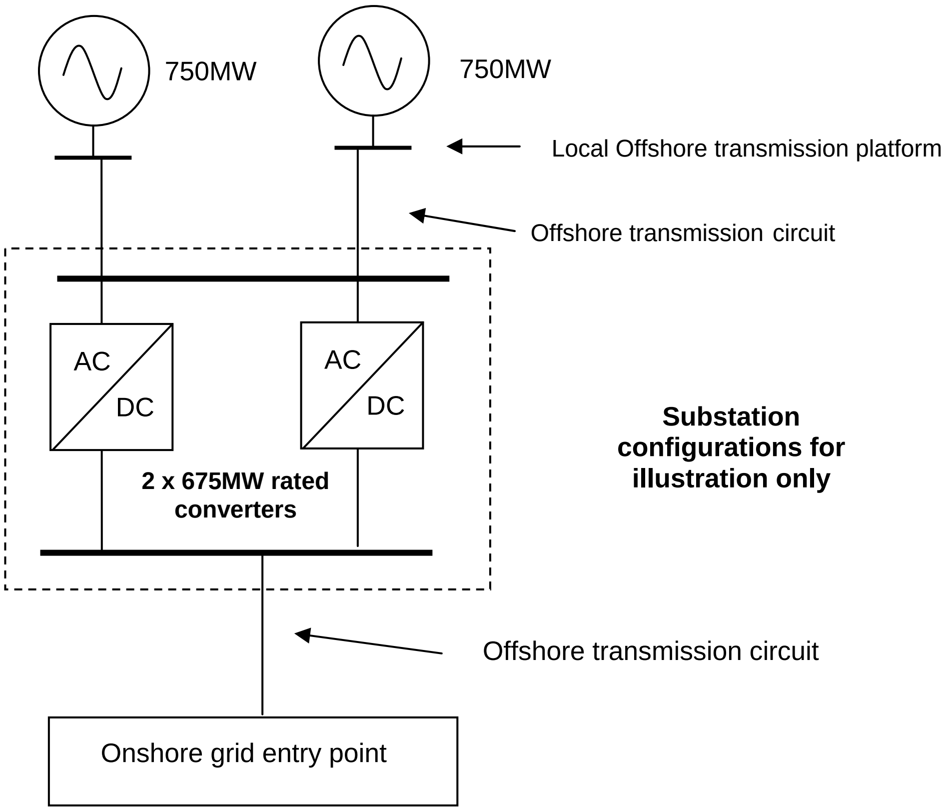


Multiple windfarm connections

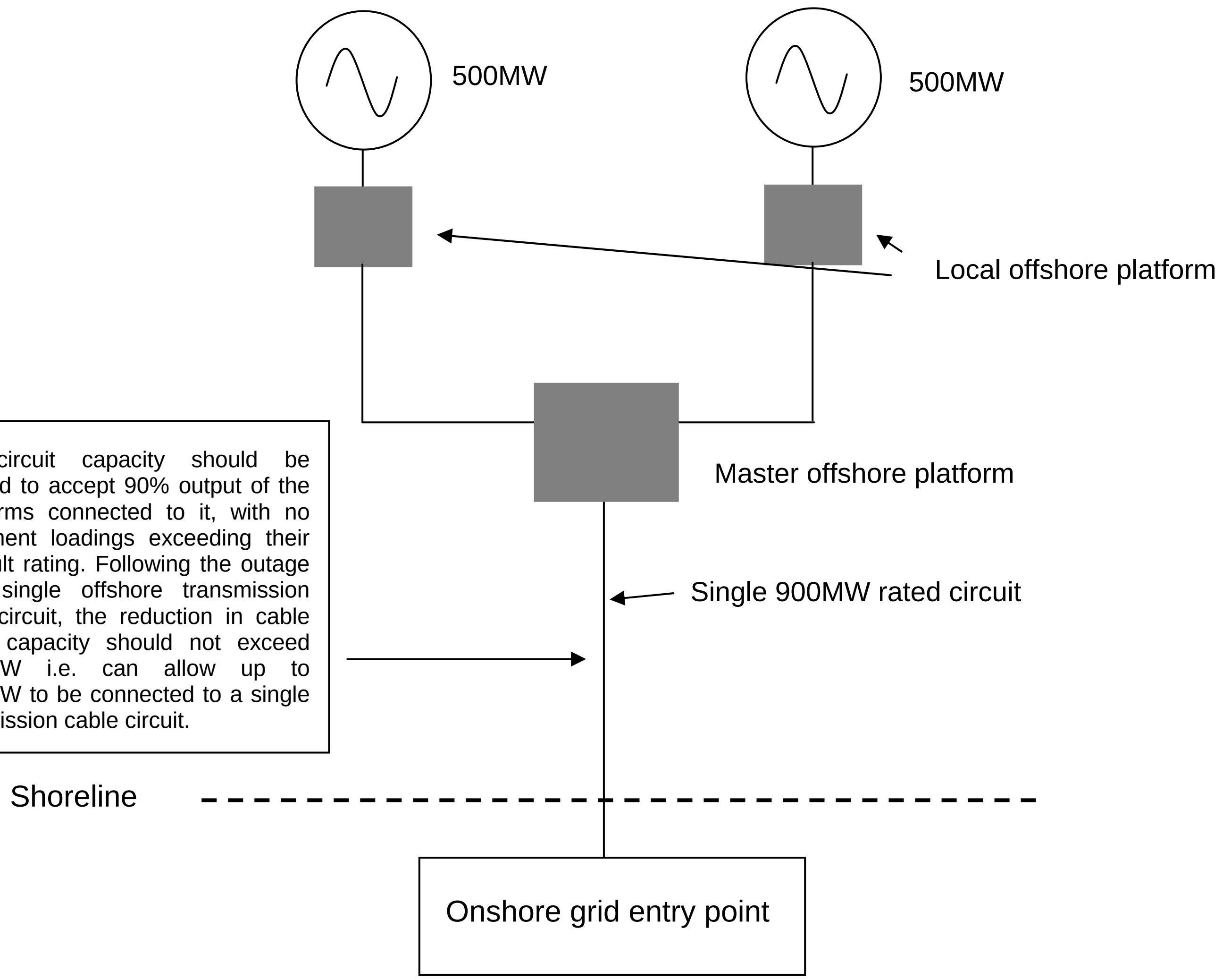




For multiple wind farm connections, the transmission capacity should be planned to accept 90% of the installed wind farm capacity. Platform capacity should be planned such that following the outage (planned or unplanned) of a single offshore platform DC converter module, the loss of power infeed shall not exceed 1000MW.



Offshore network capacity (AC and DC cables)



The circuit capacity should be planned to accept 90% output of the windfarms connected to it, with no equipment loadings exceeding their pre-fault rating. Following the outage of a single offshore transmission cable circuit, the reduction in cable circuit capacity should not exceed 1500MW i.e. can allow up to 1500MW to be connected to a single transmission cable circuit.

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Definition of N-2, N-1 and N-0 and proposed arrangements

Existing standards definitions

1. **N-1 = Capacity to export full generation under single circuit outage**

GBSQSS wording:

Following the fault outage of a single offshore transmission circuit, no loss of power infeed shall occur.

2. **N-2 = Capacity to not disconnect greater than 1320MW of generation under second circuit outage**

GBSQSS wording:

Following the outage of a single offshore transmission circuit during the planned outage of an offshore transmission circuit, the reduction in circuit capacity should not exceed the infrequent infeed loss risk.

Definitions considered during the cost benefit analysis

3. **N-0 = No capacity provided under single circuit outage**

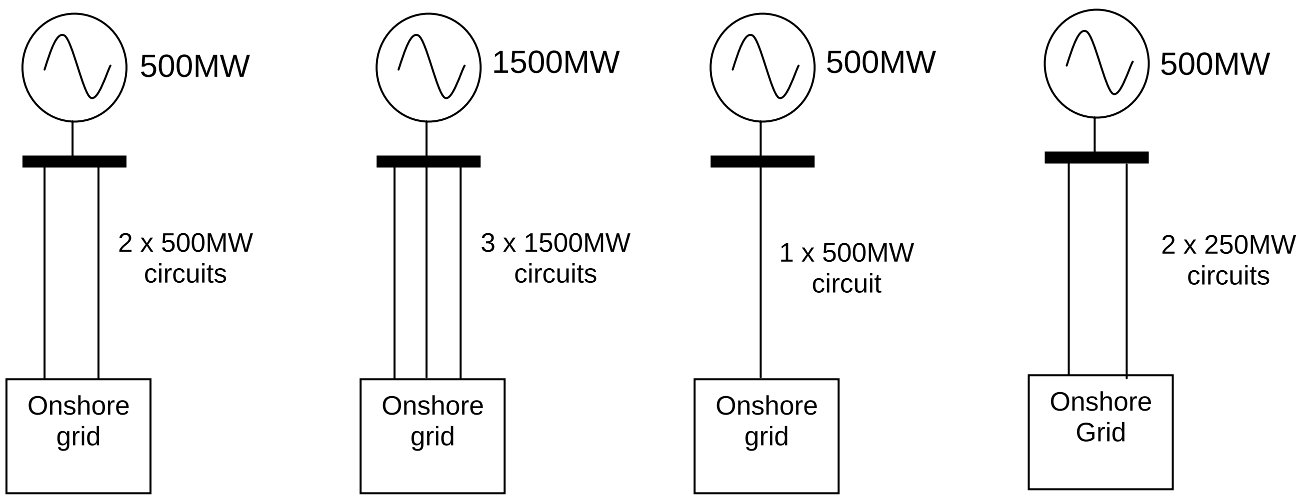
Suggested GBSQSS wording:

Following the fault outage of a single offshore transmission circuit, the loss of power infeed shall not exceed the normal infeed loss risk (1000MW).

4. “**N-1” = Capacity to export X% of generation under single circuit outage**

Suggested GBSQSS wording:

Following the fault outage of a single offshore transmission circuit, the loss of power infeed shall not exceed X% registered capacity of generation.



Definition 1: N-1 = Capacity to export full generation under single circuit outage

Definition 2: N-2 = Capacity to not disconnect greater than 1320MW of generation under second circuit outage

Definition 3: N-0 = No capacity provided under single circuit outage

Definition 4: N-1 = Capacity to export X% of generation under single circuit outage

X = 50 in this example

Appendix 6
Sub-group assumptions

Assumptions

ID	Raised On	Raised By	Description	Status	Last Updated	Comments
A001	09-Jun-06	Andy Hiorns	Offshore transmission circuitsare classified as 132kV and above.	Accepted	27-Jun-06	
A002	09-Jun-06	Andy Hiorns	Integreation of intermittent generation into onshore transmission networks is being considered separately. Integration of intermittent generation into offshore networks is outside the scope of this group.	Accepted	27-Jun-06	
A003	09-Jun-06	Andy Hiorns	Offshore transmission networks will be considered as radial networks connected to a single onshore grid connection entry point. Should the nodes parallel the onshore network they would become part of the MITS and therefore subject to onshore security standards.	Accepted	27-Jun-06	
A004	09-Jun-06	Andy Hiorns	This subgroup will consider only the conenction of wind generation to offshore networks and not the conenction of other technologies (Tidal generation / demand etc).	Raised		This will be made as a working assumption, with the groups proposition flagged up to OTEG at an early stage.
A005	09-Jun-06	Andy Hiorns	Generation circuits are to be as defined in the introduction to paper number **Offshore SQSS 1.**	Accepted	27-Jun-06	
A006	09-Jun-06	Bridget Morgan	Any recommendation for future development of the SQSS will be noted in the groups overall recommendation to OTEG. This could be a result of advances in technology for power transmission, generation technology changes etc.	Accepted	27-Jun-06	
A007	09-Jun-06	Bridget Morgan	Any consideration of distribution network standards are outside the scope of this sub group. If it is believed to be an issue it will be raised in recommendation to OTEG.	Accepted	27-Jun-06	
A008	09-Jun-06	Cornel Brozio	Offshore network defined as the network up to the first substation the circuit/s reach onshore.	Accepted	27-Jun-06	
A009	09-Jun-06	Andy Hiorns	Technical code updates are outside the scope of this group. These works will be considered at a later date.	Accepted	27-Jun-06	
A010	09-Jun-06	Andy Hiorns	Commercial frameworks will be developed as appropriate, and in accordance with the optimum design solution.	Accepted	27-Jun-06	
A011	28-Jul-06	Andy Hiorns	Scope of offshore transmission system will be defined as; the connection from the onshore substation up to the disconnector on the busbar side of the outgoing windfarm feeder circuit (option 3 in the scope of offshore transmission system paper). The scope of the offshore transmission security standards will therefore include the offshore platform transformers and LV substation switchgear. Any changes to the default scope of an offshore transmission system will require a re-assessment of the offshore security standards.	Accepted	18-Aug-06	
A012	28-Jul-06		The Grid Code review work will need to take account of the default scope of offshore transmission systems assumed by the GB SQSS review sub group. (note assumption A011, but subject to change as development work progresses).	Accepted	18-Aug-06	
A013	04-Aug-06	Philip Baker	The existing GB SQSS allows a transmission licensee to design a network to a higher level of security than required by the minimum, deterministic criteria defined in the standard provided the additional works can be economically justified. This facility should be included in the offshore security standards.	Accepted	18-Aug-06	
A014	18-Aug-06	Edgar Goddard	Cost benefit analysis will consider only the use of currently available technology, the results of which will be used to form the sub-roup recommendation. Sensitivity assessments will take account of technology thought reasonably to be available, along with technologies proposed to be available in the future.	Accepted	1-Sep-06	
A015	18-Aug-06	Edgar Goddard	All data to be used in the cost benefit analysis will be as agreed at the sub-group teleconference, 18/08/06.	Accepted	1-Sep-06	