

**NETS SQSS**

**Review of Requirement of Onshore Connection  
Facilities for Offshore Wind Farm Connections  
(GSR014)**

**Working Group Report**

**January 2014**

## Executive Summary

This document summarises the results of a cost-benefit analysis (CBA) based on the Spackman methodology<sup>1</sup> developed to determine the optimal design of offshore transmission grid to connect to onshore electricity networks. The CBA methodology implemented was used for the review of the NETSO Security and Quality of Supply Standard (SQSS) for Offshore Transmission Networks, as a part of the activities carried out by the NETS SQSS GSR 014 working group.

It was assumed that the onshore elements of the offshore transmission system, for which a schematic diagram is presented in Figure 1, will operate at 400kV. Furthermore, such systems will be composed of cable underground network, circuit breakers, disconnectors, transformers and the on-shore substation that connects the offshore system to the onshore one.

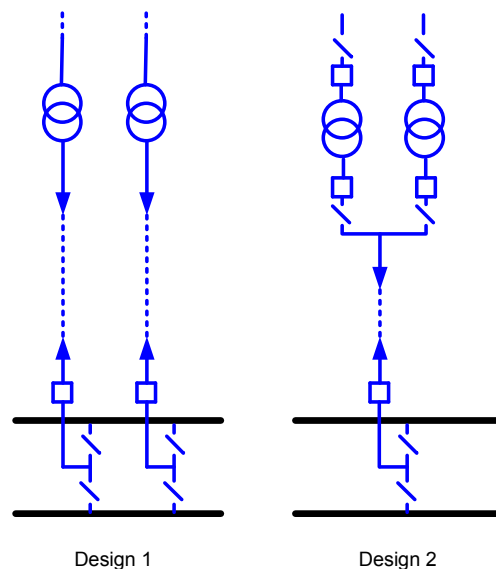


Figure 1: Schematic diagram offshore transmission system design considered

A balancing exercise between the following two broad categories of costs is carried out to determine the optimal network design:

- cost of offshore transmission system investment, that is composed of:
  - costs of underground cable network
  - cost of transformers
  - cost of onshore switchgear

<sup>1</sup> The Spackman approach is the most appropriate method for CBAs in cases where a firm finances the investment, but benefits mainly accrue to consumers and/or the wider public  
Spackman Method, Published by the Joint Regulators Group (JRG), Discounting for CBA's involving private investment, but public benefit, 25 July 2012

- capitalised cost of expected constrained energy due to preventive and corrective maintenance over the period of the asset life

Based on evaluating the above two cost components for the two offshore transmission system configurations we have identified optimal designs for a range of wind farms with 250MW, 500MW and 1000 MW and onshore cable length of 50m.

The CBA using Spackman approach calculates the cost benefit over the assumed 20 year life of the wind farm assuming pre-tax Weighted Average Cost of Capital (WACC) of 7.9% (IDC, Interest During Construction), and Social Time Preference Rate (SPTR) of 3.5%.

The energy cost used in CBA is assumed to be £150/MWh, which is equal to 2 ROC's plus energy price. This value also coincides with the strike price under EMR for connection of offshore winds farms with connection dates before 2017. That price will be reduced to £135/MWh for wind farms connecting after 2017; however, the change in energy price does not have a material impact on overall solution. The complete results of how capital and operational costs were calculated as part of the Spackman approach can be seen in the Appendices attached to this report.

The Spackman approach was used to compare the Costs and Benefits between Design 1 and Design 2

1. The capital costs used in this example are transmission investment cost of each design. The transmission capital costs are converted into an annual cost using IDC value 7.9%. This gives a stream of financing costs or appropriate time profile of annualised costs, which are included as a part of the cost side of the cost benefit analysis.
2. The benefits are the constraint costs which were calculated for each design and included for each year. The Social Time Preference Rate (STPR) of 3.5 % was then applied in discounting these costs, as recommended by the HM treasury green book.

We considered both AIS and GIS switchgear solutions for different MW's.

The results from Spackman Approach and Calculations of Constraint Costs are presented in the Appendix B and C respectively.

*Results for 250MW:*

The results show that Net Present Value (NPV) for 250 MW (AIS) for Design 1 in comparison to Design 2 is **£6.90m**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

The results show that Net Present Value (NPV) for 250 MW (GIS) for Design 1 in comparison to Design 2 is **£11.13m**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

*Results for 500MW:*

The results show that Net Present Value (NPV) for 500 MW (AIS) for Design 1 in comparison to Design 2 is **£11.15m**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

The results show that Net Present Value (NPV) for 500 MW (GIS) for Design 1 in comparison to Design 2 is **£18.87m**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

*Results for 1000 MW:*

The results show that Net Present Value (NPV) for 1000 MW (AIS) for Design 1 in comparison to Design 2 is **£20.80m**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

The results show that Net Present Value (NPV) for 1000 (GIS) MW for Design 1 in comparison to Design 2 is **£36.64**, as seen by the consumers, which makes Design 1 more cost beneficial in comparison to Design 2.

## Table of Contents

Executive Summary .....	2
<b>Table of Contents</b> .....	<b>5</b>
1. Introduction .....	6
2. Offshore Transmission Network Topologies .....	8
3. Cost Benefit Analysis Methodology .....	9
4. Evaluation of Expected Energy Curtailed (EEC) .....	10
5. How the proposed designs were costed? .....	11
6. Key Findings.....	13
7. Recommendations .....	14
6 APPENDIX A – An Illustrative Example of the Spackman Approach	15
7 APPENDIX B – Examples of Calculation of Constraint Costs .....	20
8 APPENDIX C – Terms of Reference (TOR).....	24

## Introduction

### 1. Introduction

The National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS), sets out a coordinated set of criteria and methodologies that transmission licensees shall use in the planning, development and operation of the National Electricity Transmission System (NETS).

The SQSS was initially developed across 1990 to 2005 for application to the onshore system of England, Wales and Scotland. In June 2009, additional criteria (namely SQSS sections 7, 8, 9 and 10) were introduced for offshore transmission systems. (Revision June 2009). An issue was raised by National Grid as the Transmission Owner (TO) to revisit the wording of section 7.13.1.1 which currently states:

*In the case of offshore power park module only connections, and where the offshore grid entry point capacity is 120MW or more, following a planned outage or a fault outage of a single AC offshore transformer circuit at the onshore AC transformation facilities, the loss of power infeed shall not exceed the smaller of either:*

*50% of the offshore grid entry point capacity; or the full normal infeed loss risk*

This current wording commonly results in onshore designs to connect an offshore wind farm having two transformers, rated at 50% of the offshore grid entry point capacity, and two high voltage bays at the onshore TO's substation. It is believed that the work undertaken in developing the offshore SQSS criteria never envisaged needing two bays to connect an offshore windfarm. The purpose of Section 7.13.1.1 is to ensure that in the event of a permanent fault on a transformer, the wind farm would not be completely disconnected from the network for the duration of the transformer replacement time which could be in the region of 18 months. The principles behind 7.13.1.1 were not believed to be intended to cover the short term loss of power infeed of the whole wind farm up to the normal infeed loss.

Therefore the aim of this study was to investigate whether the current requirement for two transformers and two high voltage substation bays where offshore cables connect to the onshore network is justified or whether two transformers connected to a single bay would be sufficient.

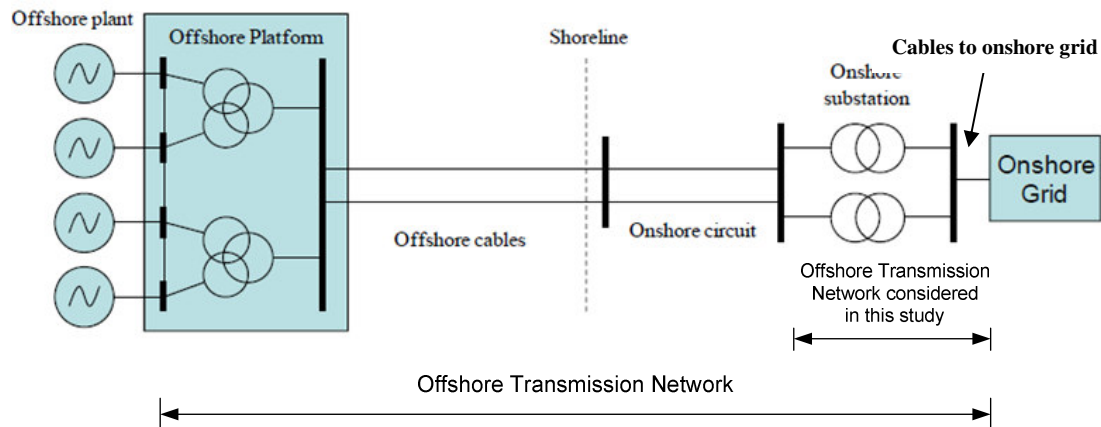
## Introduction

This report describes how the study was undertaken and makes recommendations on NETS SQSS amendments to section 7.13.1.1.

The terms of reference (ToR) and working group membership can be found in Appendix C.

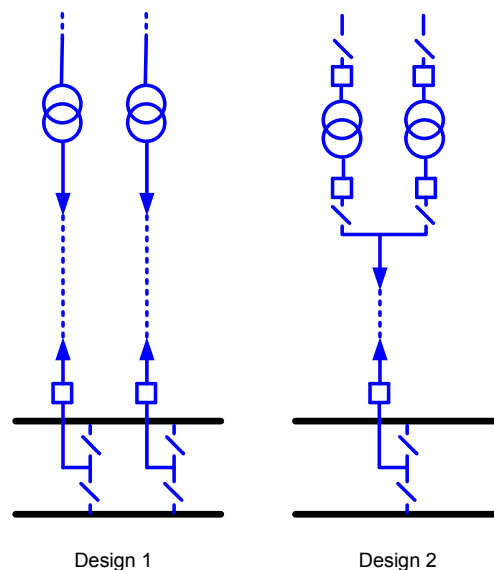
## 2. Offshore Transmission Network Topologies

The section of the offshore transmission network analysed in this study is shown in Figure 2.1 below (only the onshore part of the offshore network is taken into consideration). Such a network will comprise of transformers, switching equipment (circuit breakers and disconnectors) as well as the cable which will connect the onshore substation to the onshore grid.



**Figure 2.1 Offshore Transmission Network**

Based on the aim of the study, two different offshore network configurations, shown in Figure 2.2, were considered. Only components shown in blue have been included in the analysis. Design 1 which is the current design most frequently used for the connection of offshore wind farms and Design 2 which is the design proposed by the Transmission Owner. The next section describes how a cost benefit approach was used to determine the optimal configuration.



**Figure 2.2: Schematic diagrams of offshore transmission network designs**



### 3. Cost Benefit Analysis Methodology

A cost benefit analysis approach was used to determine the optimum economic and technical solution for an offshore network connecting to the onshore electricity grid system. This analysis identified the key parameters which impact on the proposed offshore design solution and considered a range of possible values to demonstrate the robustness of proposals against a range of input data.

This analysis has considered generic wind farm sizes of 250MW, 500 MW and 1000 MW along with all characteristics of the onshore switching assets to be installed in the network that will have an impact on the outcome of the analysis.

The developed cost benefit analysis is employed to find optimal tradeoffs between the following two broad categories of costs:

- cost of offshore transmission system investment, that is composed of:
  - cost of underground cable<sup>2</sup>
  - cost of associated switchgear equipment (circuit breakers and disconnectors)
  - cost of transformers
  
- capitalised cost of expected constrained energy due to preventive and corrective maintenance over the period of the asset life.

Based on evaluating the above two cost components for the offshore transmission system configurations shown in Figure 2.2, the optimal design has been identified.

#### **Sensitivity analysis on how the length of onshore cable affects the Cost Benefit Analysis Results**

The sensitivity analysis to increase the cost of cable costs was performed. The sensitivity analysis considers a range of costs between £1.8M/km up to £2.5M/km and the cable distance from 50 – 250m.

The results of sensitivity analysis showed smaller NPV benefit (the values are in range of 1% to 5% smaller) in comparison with initial cost benefit analysis however that results did not change the final conclusion. The complete results on Spackmana

Approach are presented in Appendix A (Sensitivity Study on cable costs - An Illustrative Example of the Spackman Approach).

#### **4. Evaluation of Expected Energy Curtailed (EEC)**

The evaluation of expected energy curtailed follows the same methodology as outlined in the report “Cost Benefit Methodology for Optimal Design of Offshore Transmission Systems”<sup>3</sup>.

The volume of energy losses and expected energy may be curtailed due to unavailability of cables and switchgears of offshore transmission networks. The methodology for this evaluation is based on the assumption that wind energy curtailed associated with every network design (and the corresponding costs) represents a long-term average (expected) value of energy curtailed. In theory, the expected value of energy curtailed can be approximately achieved from operating a large number of offshore schemes over a relatively long period of time. In practice, there will be potentially significant variations in the energy curtailed associated with individual wind farms, as they may experience higher or lower number of outages than the expected long-term average, and hence higher or lower levels of curtailed energy than the long-term average.

The output of a wind farm is fundamental to the output of the cost benefit analysis due to a need to establish the volume of energy curtailed during fault and maintenance of components of individual offshore transmission system designs.

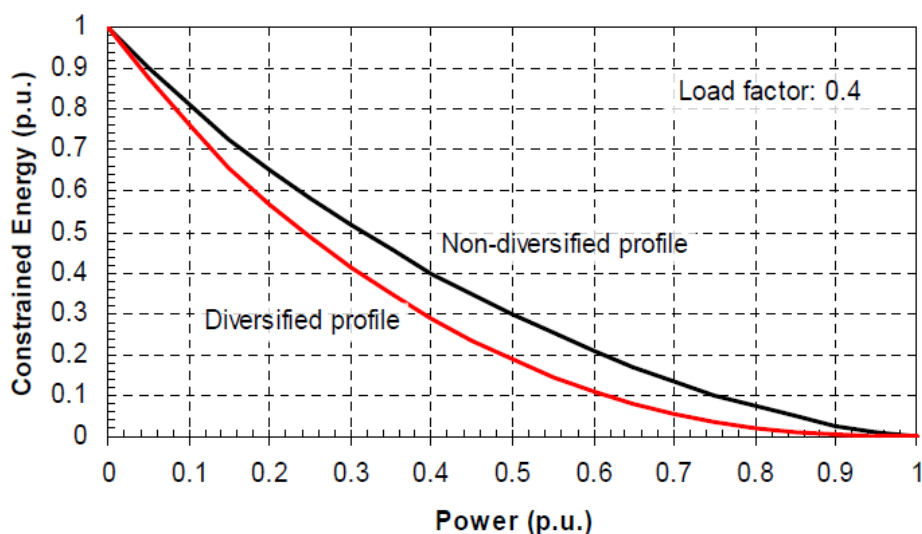
In this analysis a normalised and diversified wind farm profile has been used with two load factors, an overall annual load factor of 40% and a load factor of 24% for periods of planned maintenance. It is assumed that planned maintenance will be carried out over the summer period during which time the load factor of the wind farm reduces to 24%.

The graph shown in Figure 3.1 has been developed to assess the constrained energy due to the reduced capacity of the offshore transmission network (Djapic & Strbac, “Cost Benefit Methodology for Optimal Design of Offshore Transmission System”, 2008). This means for the loss of 50% or 0.5 p.u. of the transmission capacity (for example a fault on one of the cables in design 1) the constrained energy is 0.2 p.u (for diversified wind output profile<sup>4</sup>) of the wind farm output.

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<sup>3</sup> *Cost Benefit Methodology for Optimal Design of Offshore Transmission Systems, Centre for Sustainable Electricity and Distributed Generation, P.Djapic, G.Strbac, July 2008*

<sup>4</sup> We consider two 40% load factor normalised wind farms output profiles. We use two extreme wind generation output profiles, diversified and non-diversified, to assess network requirements. For large wind farms, or groups of wind farms, spread across a very wide geographical area the diversity effects may be significant (“diverse” wind out profile may be appropriate), while small



**Figure 0.1: Constrained Wind Energy**

The cost of EEC is given by the expression below:

Expected Energy Curtailed Cost = Expected Energy Curtailed per year X Capitalised Energy Cost

The explanation of the calculation is explained below:

**Expected Energy Curtailed per year** = Wind Farm Output X Constrained Energy Factor X Load factor X failure/maintenance rate X number of circuits X duration of failure/maintenance

**Wind Farm Output:** 250MW, 500MW and 100MW

**Load Factor:** 40% and 24%

Constrained Energy: based on graph in Figure 3.1 constrained energy is 20%

Assumption for **Capitalised Energy Cost** is £150/MWh<sup>5</sup>.

## 5. How the proposed designs were costed?

From information provided by National Grid on maintenance practice and repair times, Table 4.1 and Table 4.2 were developed. Failure rates of components were obtained from published reliability reports as well as from internal National Grid

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wind farms covering a small geographical area will be characterized by lower diversity (“non-diverse” wind output profiles may be appropriate). However, no specific wind data was available to make firm recommendations regarding the application of diverse or non-diverse wind profiles in relation to specific areas that wind farms may occupy.

<sup>5</sup> The energy cost used in CBA is assumed to be £150/MWh, which is equal to 2 ROC's plus energy price. This value also coincides with the strike price under EMR for connection of offshore wind farms with connection dates before 2017. That price will be reduced to £135/MWh for wind farm connecting after 2017

sources. The table below details the input data and their source for the cost benefit analysis where MTTR – mean time to repair, MTBM – mean time between planned maintenance, MTTM – mean time to maintain.

Table 4.1

Failure					
Equipment	GIS		AIS		Source
	FR	Unit	FR	Unit	
Cable	0.30%	km.years	0.30%	km.years	NG <sup>6</sup>
Circuit Breaker	0.53%	per year	0.53%	per year	Cigre <sup>7</sup>
Disconnecter	0.05%	years	0.29%	years	Cigre
Transformer	0.33 %	years	0.33%	years	NG
	MTTR	Unit	MTTR	Unit	
Cable	1344	hrs	1344	hrs	NG
Circuit Breaker	504	hrs	504	hrs	NG
Disconnecter	504	hrs	504	hrs	NG
Transformer	1440	hrs	1440	hrs	NG

Table 4.2

Maintenance					
Equipment	GIS		AIS		Source
	MTBM	Unit	MTBM	Unit	
Cable	6	years	6	years	NG
Circuit Breaker	6	years	6	years	NG
Disconnecter	18	years	6	years	NG
Transformer	1	years	1	years	NG
	MTTM	Unit	MTTM	Unit	
Cable	12	hrs	12	hrs	NG
Circuit Breaker	48	hrs	80	hrs	NG
Disconnecter	10	hrs	24	hrs	NG
Transformer	147	hrs	147	hrs	NG

The capitalised cost of expected energy constrained was calculated as the sum of energy constrained due to component failures plus the energy constrained due to

<sup>6</sup> Information provided by National Grid

<sup>7</sup> Cigre, “Final Report of the 2004 – 2007 International Enquiry on Reliability of High Voltage Equipment”, 2012

scheduled maintenance of components. The assessment period was assumed to be 20 years.

## **Spackman Methodology**

The approach to discounting used in this analysis is that promoted by the Joint Regulators Group in its technical paper “Discounting for CBAs involving private investment for public benefit” where a firm finances the investment but the benefits accrue mainly to the wider public. This so called “Spackman Approach” has been accepted by Ofgem as an appropriate means for National Grid to evaluate transmission projects over the price control period, RIIO-T1. Benefits are quantified in terms of avoided constraint costs. Under this approach the CBA follows a two step process:

- i. First, the capital costs are converted into annual costs using the companies weighted average cost of capital (WACC). For the purposes of this analysis a WACC of 6.25% was used.
- ii. Second, the social time preference rate (STPR) of 3.5% is used to discount all the costs and benefits, as recommended by the HM Treasury Green Book.

The results showing the outcome of the Spackman approach for the two designs considered are included as Appendix B.

## **6. Key Findings**

The results from Spackman Approach and Calculations of Constraint Costs are presented in Appendices A and B.

### **Results for 250MW:**

The results show that Net Present Value (NPV) for 250 MW (AIS) for Design 1 in comparison to Design 2 is **£6.90m**, as seen by the consumer, which makes Design 1 more cost beneficial in comparison to Design 2.

The results show that Net Present Value (NPV) for 250 MW (GIS) for Design 1 in comparison to Design 2 is **£11.30m**, as seen by the consumer, which makes Design 1 more cost beneficial in comparison to Design 2.

### **Results for 500MW:**

The results show that Net Present Value (NPV) for 500 MW (AIS) for Design 1 in comparison to Design 2 is **£11.15m**, as seen by the consumer, which makes Design 1 more cost beneficial in comparison to Design 2.

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The results show that Net Present Value (NPV) for 1000 (GIS) MW for Design 1 in comparison to Design 2 is **£36.64m** as seen by the consumer, which makes Design 1 more cost beneficial in comparison to Design 2.

The NPV's demonstrate that in most cases the Design 1 option has a lower NPV than the Design 2 option for the different wind farm sizes. If there are circumstances where the on-shore substation costs are very high (for example Design 1 would require a new substation build), then it may be appropriate to use Design 2. In such cases, a cost benefit assessment should be carried out to demonstrate the most cost effective design.

## **7. Recommendations**

Based on the presented results the review group is proposing the following changes into NETS SQSS text:

### *7.13.1.1.*

*In the case of offshore power park module only connections, and where the offshore grid entry point capacity is 120 MW or more, following a planned outage or a fault outage of a single ~~AC offshore transformer circuit~~ **AC offshore transmission circuit** at the onshore AC transformation facilities *or between the onshore AC transformation facilities and the Onshore Transmission System*, the loss of power infeed shall not exceed the smaller of either:*

- *50% of the offshore grid entry point capacity,*
- *or the full normal infeed loss risk;*

## 6 APPENDIX A – An Illustrative Example of the Spackman Approach

DESIGN 1 - TWO BA\DESIGN 2 - ONE BAY

250 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.70																			
Trans Inv Cost D2	9.54																			
Diff Trans Inv Costs	-1.84																			
Annulity costs (6.25%)	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Const. costs D1	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Const. costs D2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Diff constr. costs	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
NPV (difference)	-6.90	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49	-0.49

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Const. costs D1	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Const. costs D2	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Diff constr. costs	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
NPV (difference)	-11.13	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78

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Const. costs D1	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Const. costs D2	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Diff constr. costs	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62
NPV (difference)	-11.15	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78

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Const. costs D1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Const. costs D2	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Diff constr. costs	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15
NPV (difference)	-18.87	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33

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Annulity costs (6.25%)	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Diff constr. costs	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30
NPV (difference)	-20.80	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46

1000 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.20																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-2.00																			
Annulity costs (6.25%)	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Diff constr. costs	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40
NPV (difference)	-36.64	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58

# Sensitivity Study on cable costs - An Illustrative Example of the Spackman Approach

Cable length 50m, cable costs £1.8M

250 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.80																			
Trans Inv Cost D2	9.50																			
Diff Trans Inv Costs	-1.80																			
Annulity costs (6.25%)	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Const. costs D1	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Const. costs D2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Diff constr. costs	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
NPV (difference)	-6.85	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48

250 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annulity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Const. costs D2	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Diff constr. costs	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
NPV (difference)	-11.00	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77

500 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.80																			
Trans Inv Cost D2	9.50																			
Diff Trans Inv Costs	-1.80																			
Annulity costs (6.25%)	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Const. costs D1	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Const. costs D2	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Diff constr. costs	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62
NPV (difference)	-11.10	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78

500 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annulity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Const. costs D2	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Diff constr. costs	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15
NPV (difference)	-18.75	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32

1000 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.80																			
Trans Inv Cost D2	9.50																			
Diff Trans Inv Costs	-1.80																			
Annulity costs (6.25%)	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Diff constr. costs	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30
NPV (difference)	-20.75	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46	-1.46

1000 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annulity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Diff constr. costs	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40
NPV (difference)	-36.51	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57



# Sensitivity Study on cable costs - An Illustrative Example of the Spackman Approach

Cable length 250m, cable costs £1.8M

250 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.50																			
Trans Inv Cost D2	9.96																			
Diff Trans Inv Costs	-1.46																			
Annuity costs (6.25%)	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Const. costs D1	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Const. costs D2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Diff constr. costs	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
NPV (difference)	-6.42																			

250 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Const. costs D2	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Diff constr. costs	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
NPV (difference)	-11.00																			

500 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.50																			
Trans Inv Cost D2	9.96																			
Diff Trans Inv Costs	-1.46																			
Annuity costs (6.25%)	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Const. costs D1	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Const. costs D2	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Diff constr. costs	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62
NPV (difference)	-10.67																			

500 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Const. costs D2	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Diff constr. costs	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15
NPV (difference)	-18.75																			

1000 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.50																			
Trans Inv Cost D2	9.96																			
Diff Trans Inv Costs	-1.46																			
Annuity costs (6.25%)	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Diff constr. costs	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30
NPV (difference)	-20.32																			

1000 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.30																			
Trans Inv Cost D2	12.20																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Diff constr. costs	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40
NPV (difference)	-36.51																			

# Sensitivity Study on cable costs - An Illustrative Example of the Spackman Approach

Cable length 50m, cable costs £2.5M

250 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.90																			
Trans Inv Cost D2	9.60																			
Diff Trans Inv Costs	-1.70																			
Annuity costs (6.25%)	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Const. costs D1	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Const. costs D2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Diff constr. costs	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
NPV (difference)	-6.73																			
250 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Const. costs D2	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Diff constr. costs	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
NPV (difference)	-11.00																			
500 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.90																			
Trans Inv Cost D2	9.60																			
Diff Trans Inv Costs	-1.70																			
Annuity costs (6.25%)	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Const. costs D1	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Const. costs D2	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Diff constr. costs	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62
NPV (difference)	-10.98																			
500 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Const. costs D2	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Diff constr. costs	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15
NPV (difference)	-18.75																			
1000 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	7.90																			
Trans Inv Cost D2	9.60																			
Diff Trans Inv Costs	-1.70																			
Annuity costs (6.25%)	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Diff constr. costs	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30
NPV (difference)	-20.63																			
1000 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuity costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Diff constr. costs	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40
NPV (difference)	-36.51																			

# Sensitivity Study on cable costs - An Illustrative Example of the Spackman Approach

Cable length 250m, cable costs £2.5M

250 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.90																			
Trans Inv Cost D2	10.10																			
Diff Trans Inv Costs	-1.20																			
Annuitiy costs (6.25%)	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Const. costs D1	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Const. costs D2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Diff constr. costs	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
NPV (difference)	-6.09	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43	-0.43

250 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuitiy costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Const. costs D2	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Diff constr. costs	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
NPV (difference)	-11.00	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77

500 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2 AIS																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.90																			
Trans Inv Cost D2	10.10																			
Diff Trans Inv Costs	-1.20																			
Annuitiy costs (6.25%)	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Const. costs D1	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Const. costs D2	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Diff constr. costs	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62	-0.62
NPV (difference)	-10.34	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73

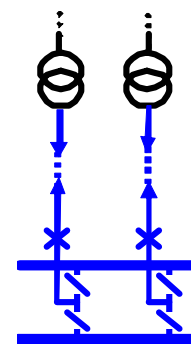
500 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2 GIS																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuitiy costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Const. costs D2	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Diff constr. costs	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15	-1.15
NPV (difference)	-18.75	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32

1000 MW																				
Des 1 vs Des 2 AIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2 AIS																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	8.90																			
Trans Inv Cost D2	10.10																			
Diff Trans Inv Costs	-1.20																			
Annuitiy costs (6.25%)	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Diff constr. costs	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30	-1.30
NPV (difference)	-19.99	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41	-1.41

1000 MW																				
Des 1 vs Des 2 GIS																				
WACC	6.25%																			
STPR	3.50%																			
CASE 1 VS 2 GIS																				
COSTS (£m)																				
YEARS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Trans Inv Cost D1	10.40																			
Trans Inv Cost D2	12.30																			
Diff Trans Inv Costs	-1.90																			
Annuitiy costs (6.25%)	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Const. costs D1	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Const. costs D2	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Diff constr. costs	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40	-2.40
NPV (difference)	-36.51	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57

# 7 APPENDIX B – Examples of Calculation of Constraint Costs

## TWO BAY – AIS



**FAILURE CABLE**

MW	Failure rate	Length (k)	Failure rate	Load Fac	Number	Duration (h)
250	0.003	0.05	0.00015	40%	2	1344
500	0.003	0.05	0.00015	40%	2	1344
1000	0.003	0.05	0.00015	40%	2	1344

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	8.064
500	16.128
1000	32.256

**Cost of e 150**

MW	Cost of e
250	1,210
500	2,419
1000	4,838

**Circuit Breaker**

MW	Failure rate	Load Fac	Number	Duration (h)
250	0.0053	0.4	2	504
500	0.0053	0.4	2	504
1000	0.0053	0.4	2	504

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	106.848
500	213.696
1000	427.392

**Transformer**

MW	Failure rate	Load Fac	Number	Duration (h)
250	0.003	0.4	2	1440
500	0.003	0.4	2	1440
1000	0.003	0.4	2	1440

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	172.8
500	345.6
1000	691.2

**Cost of e 150**

MW	Cost of e
250	25920
500	51840
1000	103680

**MAINTANANCE**

**Circuit Breaker**

MW	MTPM	Load Fac	Number	Duration (h)
250	0.166667	24%	2	80
500	0.166667	24%	2	80
1000	0.166667	24%	2	80

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	0
500	0
1000	0

**Cost of e 150**

MW	Cost of e
250	0
500	0
1000	0

**Protection**

MW	MTPM	Load Fac	Number	Duration (h)
250	0.166667	24%	2	0
500	0.166667	24%	2	0
1000	0.166667	24%	2	0

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	0
500	0
1000	0

**Cost of e 150**

MW	Cost of e
250	0
500	0
1000	0

**DISCONNECTOR**

MW	Failure	Load Factor	Number	Duration (h)
250	0.003	0.4	4	504
500	0.003	0.4	4	504
1000	0.003	0.4	4	504

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	116.928
600	233.856
1000	467.712

**Failure rate**

MW	Failure rate
250	0.0053
600	0.0029
1000	0.0015

**Cost of e 150**

MW	Cost of e
250	17539.2
600	35078.4
1000	70156.8

**MAINTANANCE**

**Disconnector**

MW	Failure	Load Factor	Number	Duration (h)
250	0.167	24%	2	0
500	0.167	24%	2	0
1000	0.167	24%	2	0

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	0
500	0
1000	0

**Cost of e 150**

MW	Cost of e
250	0
500	0
1000	0

**TRANSFORMER**

MW	MTPM	Load Factor	number	Duration (h)
250	1	24%	2	147
500	1	24%	2	147
1000	1	24%	2	147

**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	3528
500	7056
1000	14112

**Cost of e 150**

MW	Cost of e
250	529200
500	1058400
1000	2116800

**COST**

**FAILURE**

Capitalised	Cable	CB	Disconnector	Transformer	Total
250	£1,210	£16,027	£17,539	£25,920	£60,696
500	£2,419	£32,054	£35,078	£51,840	£121,392
1000	£4,838	£64,109	£70,157	£103,680	£242,784

**MAINTANANCE**

Capitalised	CB	Disconnector	Protection	Transformer	Total
250	£0	£0	£0	£529,200	£529,200
500	£0	£0	£0	£1,058,400	£1,058,400
1000	£0	£0	£0	£2,116,800	£2,116,800

**TOTAL COST 1**

MW	Total Cost
250	£589,896
500	£1,179,792
1000	£2,359,584

**COST 2**

Capitalised cost for failure	CB	disconnector	cable	transformer
Failure rate	0.0053	0.0029	0.00015	0.003
COST (£)	1,000,000	100,000	1,000,000	2,500,000
	10600	1160	300	15000

**COST 2 TOTAL**

MW	Total Cost
250	£27,060

**COST 3**

Capital cost	CB	Disconnectors	Bay	Cable	Transformer
2	4	2	2	2	
742,000	90,000	400,000	12,500	2,500,000	
1,484,000	360,000	800,000	25,000	5,000,000	
<b>COST 3 TOTAL</b>	<b>£7,669,000</b>				

**OPERATION/CAPITAL**

TOTAL	MW	Operation	Capital	Total
250	£8,285,956	£589,896	£7,696,060	
500	£8,875,852	£1,179,792	£7,696,060	
1000	£10,055,644	£2,359,584	£7,696,060	

**TRANSFORMER**

MW	MTPM	Load Factor	number	Duration (h)
250	1	24%	2	147
500	1	24%	2	147
1000	1	24%	2	147

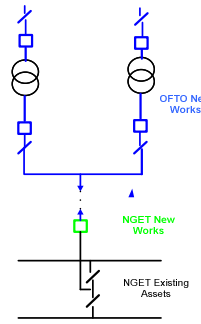
**Energy not supplied (MWh)**

MW	Energy not supplied (MWh)
250	3528
500	7056
1000	14112

**Cost of e 150**

MW	Cost of e
250	529200
500	1058400
1000	2116800

**ONE BAY – AIS**



**FAILURE**

**CABLE**

MW	Failure rate	Length (km)	Failure rate	Load Factor	Number	Duration (h)
250	0.003	0.05	0.00015	40%	1	1344
500	0.003	0.05	0.00015	40%	1	1344
1000	0.003	0.05	0.00015	40%	1	1344

Energy not supplied (MWh)	250	20.16
	600	40.32
	1000	80.64
Cost of energy (£)	250	3,024
	600	6,048
	1000	12,096

**COST**

FAILURE	Cable	CB	Disconnector	Transformer	Total	
Capitalis	250	£3,024	£136,231	£292	£25,920	£165,468
	500	£6,048	£272,462	£585	£51,840	£330,935
	1000	£12,096	£576,979	£1,169	£103,680	£693,924

MAINTANANCE	CB	Disconnector	Protection	Transformer	Total	
Capitalis	250	£120,600	£78,000	£18,000	£529,200	£745,800
	500	£241,200	£156,000	£36,000	£1,058,400	£1,491,600
	1000	£482,400	£312,000	£72,000	£2,116,800	£2,983,200

**CB**

MW	Failure	Load Factor	Number	Duration (h)
250	0.005	0.4	3	504
500	0.005	0.4	3	504
1000	0.005	0.4	3	504

Energy not supplied (MWh)	250	908.208
	500	1816.416
	1000	3846.528
Cost of energy (£)	250	136,231
	500	272,462
	1000	576,979

**Disconnector**

MW	Failure rate	Load Factor	Number	Duration (h)
250	0.0029	0.4	2	504
500	0.0029	0.4	2	504
1000	0.0029	0.4	2	504

Energy not supplied (MWh)	250	292.32
	500	584.64
	1000	1169.28
Cost of energy (£)	250	43848
	500	87696
	1000	175392

TOTAL COST 1	250	£911,268
	500	£1,822,535
	1000	£3,677,124

**TRANSFORMER**

MW	Failure	Load Factor	Number	Duration (h)
250	0.003	0.4	2	1440
500	0.003	0.4	2	1440
1000	0.003	0.4	2	1440

Energy not supplied (MWh)	250	172.8
	500	345.6
	1000	691.2
Cost of energy (£)	250	25920
	500	51840
	1000	103680

COST 2	CB	disconnector	cable	transformer
Failure rate	0.0053	0.0029	0.00015	0.003
COST (£)	1,000,000	100,000	1,000,000	2,500,000
	26500	1160	150	15000

COST 2 TOTAL	£42,810
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Energy not supplied (MWh)	250	146.16
	500	292.32
	1000	584.64
Capital cost	250	21924
	500	43848
	1000	87696

Cost 3	CB	Disconnectors	Bay	Cable	Transformer
COST 3	5	4	1		2
Capital cost	742,000	90,000	400,000	12,500	2,500,000
	3,710,000	360,000	400,000	12,500	5,000,000
COST 3 TOTAL	£9,482,500				

**TRANSFORMER**

MW	MTBM	Load Factor	number	Duration (h)
250	1	24%	2	147
500	1	24%	2	147
1000	1	24%	2	147

Energy not supplied (MWh)	250	3528
	500	7056
	1000	14112
Cost of energy (£)	250	529,200
	500	1,058,400
	1000	2,116,800

**DISCONNECTOR**

MW	MTBM	Load Factor	number	Duration (h)
250	0.166667	24%	4	24
500	0.166667	24%	4	24
1000	0.166667	24%	4	24

Energy not supplied (MWh)	250	520
	500	1040
	1000	2080
Cost of energy (£)	250	78,000
	500	156,000
	1000	312,000

TOTAL C	250	£10,436,578	£911,268	£9,525,310
	500	£11,347,845	£1,822,535	£9,525,310
	1000	£13,202,434	£3,677,124	£9,525,310

PROTECTION	MW	MTBM	Load Factor	number	Duration (h)
	250	0.166666667	24%	1	12
	500	0.166666667	24%	1	12
	1000	0.166666667	24%	1	12

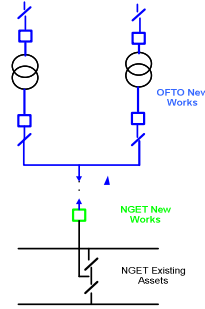
Energy not supplied (MWh)	250	120
	500	240
	1000	480
Cost of energy (£)	250	18,000
	500	36,000
	1000	72,000

**CB**

MW	MTBM	Load Factor	number	Duration (h)
250	0.167	24%	3	80
500	0.167	24%	3	80
1000	0.167	24%	3	80

Energy not supplied (MWh)	250	804
	500	1608
	1000	3216
Cost of energy (£)	250	120,600
	500	241,200
	1000	482,400

**ONE BAY – GIS**



**FAILURE CABLE**

MW	Failure rate p	Length (km)	Failure rate	Load Factor	Number of	Duration (h)
250	0.003	0.05	0.00015	40%	1	1344
500	0.003	0.05	0.00015	40%	1	1344
1000	0.003	0.05	0.00015	40%	1	1344

Energy not supplied (MWh)	250	600	1000
	20.16	40.32	80.64

Cost of ener	150
	250 3,024
	600 6,048
	1000 12,096

**COST**

FAILURE Capitalised c	Cable	CB	Disconnector	Transformer	Total
250	£3,024	£56,095	£15,876	£25,920	£100,915
500	£6,048	£112,190	£37,800	£51,840	£207,878
1000	£12,096	£224,381	£75,600	£103,680	£415,757

MAINTANANCE Capitalised c	CB	Disconnector	Protection	Transformer	Total
250	£504,000	£28,800	£18,000	£529,200	£1,080,000
500	£1,008,000	£57,600	£36,000	£1,058,400	£2,160,000
1000	£2,016,000	£115,200	£72,000	£2,116,800	£4,320,000

**CB**

MW	Failure	Load Factor	Number of C	Duration (h)
250	0.005	0.4	3	504
500	0.005	0.4	3	504
1000	0.005	0.4	3	504

**Disconnector**

MW	Failure rate	Load Factor	Number	Duration (h)
250	0.0005	0.4	4	504
500	0.0005	0.4	4	504
1000	0.0005	0.4	4	504

**TOTAL COST 1**

250	£1,180,915
500	£2,367,878
1000	£4,735,757

Energy not supplied (MWh)	250	500	1000
	373.968	747.936	1495.872
	56,095	112,190	224,381

MW	Failure rate	Load Factor	Number	Duration (h)
250	0.0005	0.4	1	504
500	0.0005	0.4	1	504
1000	0.0005	0.4	1	504

**COST 2**

Failure rate	CB	disconnector	cable	transformer
0.0053	0.0005	0.00015	0.003	
COST (£)	1,000,000	100,000	1,000,000	2,500,000
	26500	200	150	15000

Energy not supplied (MWh)	250	500	1000
	100.8	201.6	403.2
	15120	30240	60480

**COST 2 TOTAL** £41,850

**TRANSFORMER**

MW	Failure	Load Factor	Number of T	Duration (h)
250	0.003	0.4	2	1440
500	0.003	0.4	2	1440
1000	0.003	0.4	2	1440

Energy not supplied (MWh)	250	500	1000
	172.8	345.6	691.2
	25920	51840	103680

Energy not supplied (MWh)	250	500	1000
	5.04	50.4	100.8
	756	7560	15120

**Cost 3\***

COST 3 Capital cost	CB	Disconnectors	Bay	Cable	Transformer
	5	4	1		2
	1,100,000	90,000	1,300,000	12,500	2,500,000
	5,500,000	360,000	1,300,000	25,000	5,000,000
<b>COST 3 TOTAL</b>	£12,185,000				

**TRANSFORMER**

MW	MTBM	Load Factor	number	Duration (h)
250	1	24%	2	147
500	1	24%	2	147
1000	1	24%	2	147

**DISCONNECTORS**

MW	MTBM	Load Factor	number	Duration (h)
250	0.166667	24%	4	24
500	0.166667	24%	4	24
1000	0.166667	24%	4	24

**OPERATIONAL CAPITAL**

TOTAL C	250	500	1000
	£13,407,765	£1,180,915	£12,226,850
	£14,594,728	£2,367,878	£12,226,850
	£16,962,607	£4,735,757	£12,226,850

Energy not supplied (MWh)	250	500	1000
	3528	7056	14112
	529,200	1,058,400	2,116,800

Energy not supplied (MWh)	250	500	1000
	192	384	768
	28,800	57,600	115,200

**CB**

MW	MTBM	Load Factor	number	Duration (h)
250	0.16666667	24%	3	80
500	0.16666667	24%	3	80
1000	0.16666667	24%	3	80

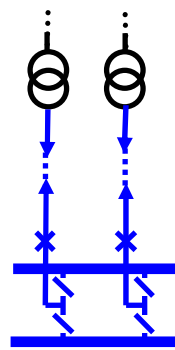
**PROTECTION**

MW	MTBM	Load Factor	number	Duration (h)
250	0.167	24%	1	12
500	0.167	24%	1	12
1000	0.167	24%	1	12

Energy not supplied (MWh)	250	500	1000
	120	240	480
	18,000	36,000	72,000

Energy not supplied (MWh)	250	500	1000
	3360	6720	13440
	504,000	1,008,000	2,016,000

**TWO BAYS – GIS**



**FAILURE**

**CABLE**

MW	Failure rate p	Length (km)	Failure rate p	Load Factor	Number	Duration (h)
250	0.003	0.05	0.00015	40%	2	1344
500	0.003	0.05	0.00015	40%	2	1344
1000	0.003	0.05	0.00015	40%	2	1344

Energy not supplied (MWh)	250	500	1000
	8.064	16.128	32.256

Cost of energy	150
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250	500	1000
1,210	2,419	4,838

**Circuit Breaker**

MW	Failure rate p	Load Factor	Number of CE	Duration (h)
250	0.0053	0.4	2	504
500	0.0053	0.4	2	504
1000	0.0053	0.4	2	504

Energy not supplied (MWh)	250	500	1000
	106.848	213.696	427.392
	16,027	32,054	64,109

**Transformer**

MW	Failure rate p	Load Factor	Number of tr	Duration (h)
250	0.003	0.4	2	1440
500	0.003	0.4	2	1440
1000	0.003	0.4	2	1440

Energy not supplied (MWh)	250	500	1000
	172.8	345.6	691.2
Cost of energy (£/M)	250	500	1000
	25920	51840	103680

**MAINTANANCE**

**Circuit Breaker**

MW	MTPM	Load Factor	Number of CE	Duration (h)
250	0.16666667	24%	2	80
500	0.16666667	24%	2	80
1000	0.16666667	24%	2	80

Energy not supplied (MWh)	250	500	1000
	0	0	0
Cost of energy (£/M)	250	500	1000
	0	0	0

**Protection**

MW	MTPM	Load Factor	Number of Pr	Duration (h)
250	0.16666667	24%	2	0
500	0.16666667	24%	2	0
1000	0.16666667	24%	2	0

**Disconnector**

MW	Failure r	Load Facto	Numbe	Duration (h)
250	0.0005	0.4	4	504
500	0.0005	0.4	4	504
1000	0.0005	0.4	4	504

Energy not supplied (MWh)	250	500	1000
	20.16	40.32	80.64
	3024	6048	12096

**MAINTANANCE**

**Disconnector**

MW	Failure r	Load Facto	Numbe	Duration (h)
250	0.1667	24%	2	0
500	0.1667	24%	2	0
1000	0.1667	24%	2	0

Energy not supplied (MWh)	250	500	1000
	0	0	0
	0	0	0
	0	0	0

Energy not supplied (MWh)	250	500	1000
	0	0	0
	0	0	0
	0	0	0

**COST**

FAILURE	Cable	CB	Disconnector	Transformer	Total
Capitalised cost	250	500	1000		
	£1,210	£16,027	£3,024	£25,920	£46,181
	£2,419	£32,054	£6,048	£51,840	£92,362
	£4,838	£64,109	£12,096	£103,680	£184,723

**MAINTANANCE**

Capitalised cost	CB	Disconnector	Protection	Transformer	Total
250	500	1000			
	£0	£0	£0	£529,200	£529,200
	£0	£0	£0	£1,058,400	£1,058,400
	£0	£0	£0	£2,116,800	£2,116,800

**TOTAL COST 1**

250	£575,381
500	£1,150,762
1000	£2,301,523

**COST 2**

Failure rate	CB	disconnector	cable	transformer
0.0053	0.0005	0.0005	0.00015	0.003
COST (£)	1,000,000	100,000	1,000,000	2,500,000
	10600	200	300	15000

**COST 2 TOTAL**

£26,100
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**COST 3**

Capital cost	CB	Disconnectors	Bay	Cable	Transformer
2	4	2	2	2	
1,100,000	90,000	1,300,000	12,500	2,500,000	
2,200,000	360,000	2,600,000	25,000	5,000,000	
<b>COST 3 TOTAL</b>	<b>£10,185,000</b>				

**OPERATIONAL CAPITAL**

TOTAL C	250	500	1000
	£10,786,481	£11,361,862	£12,512,623
	£575,381	£1,150,762	£2,301,523
	£10,211,100	£10,211,100	£10,211,100

**Transformer**

MW	MTPM	Load Factor	number	Duration (h)
250	1	24%	2	147
500	1	24%	2	147
1000	1	24%	2	147

Energy not supplied (MWh)	250	500	1000
	3528	7056	14112
Cost of e	250	500	1000
	529200	1058400	2116800

## 8 APPENDIX C – Terms of Reference (TOR)

### Group members:

Mike Lee	(Transmission Capital)
Ana Rodriguez	(Scottish Power)
Chuan Zhang	(The Crown Estate)
Michael Gordon	(RWE)
Shijun Yi	(Centrica)
Biljana Stojkowska	(NGET)
Enda Molloy	(NGET)
John.Zammit-Haber	(NGET)
David Gray	(OFGEM)

### NETS SQSS Working Group (GSR014) – Offshore Transformer Circuit Requirements

Background: The NETS SQSS criterion (7.13.1.1) ensures that in the event of a permanent fault on a transformer, the wind farm would not be completely disconnected from the network for the duration of the replacement time. This commonly results in onshore designs to connect an offshore wind farm having two transformers, rated at 50% of the offshore grid entry point capacity, and two HV circuit breakers/bays at the onshore transmission owner's substation. The principles behind 7.13.1.1 were not believed to be intended to cover the short term loss of power infeed of the whole wind farm up to the normal infeed loss.

Objective: The aim of the working group is to investigate whether the current requirements for two transformers and two substation bays where offshore cables connect to the onshore network is justified or whether two transformers connected to a single bay would be sufficient.

**Scope:** The working group scope is anticipated to be as follows:

- Review of assumptions used to develop the current SQSS wording in paragraph 7.13.1.1.
- Identify the maintenance and failure rate data for the onshore connection facilities (AC and DC).
- Perform a cost benefit analysis based on generic network designs.
- Analyse the implications for each stakeholder.
- If required, propose changes to current wording of 7.13.1.1.

**Constitution:** The working group comprises of membership from National Grid (SO and TO), OFTO (Transmission Investment), OFGEM, the Crown Estate and Industry representatives (RWE Innogy and Scottish Power Renewables). The working group will be chaired by Mike Lee (Transmission Capital).

**Meetings:** The team will meet approximately monthly.

**Reporting:** The team reports to the NETS SQSS Review Group under SQSS Governance.