SUMMARY

PB Power was commissioned to assess the capability of the electricity grid in the North East of England to accept the new renewable generation identified by the Regional Renewable Energy Strategy.

This study has used the geographic areas of potential renewable generation developed by the overall Strategy. Note that in order to be able to model the grid and identify connection solutions, indicative project locations were chosen. These should be regarded as illustrative locations only, and no implication that actual projects should be located there is intended. Much of the renewable generation is onshore wind power, including exploitation of wind resources in the Kielder area with up to 500 MW of capacity installed.

Around 7100 MW of fossil fuel generation and interconnector capacity is planned for the region by 2009/10. Given that peak demand in the region is expected to rise to only 3600 MW by 2009/10 and 3800 MW by 2019/20, the region will continue to be a power exporter, routing power south through the transmission network. The total capacity of all the renewables projects is approximately 1660 MW, representing the maximum power that would be produced from all the wind and other projects operating at full output at the same time.

Most of the renewables projects, with generating capacities of 50 MW or more, will require connection at 66 kV or higher voltages. The projects can be grouped into two general categories:

- Generation in remote rural areas, distant from the grid and with very small local loads. Power will need to be exported from the area, requiring new lines to reach grid connection points.

- Generation in the more populated, coastal areas with nearby grid connections and significant local load. These projects can be considered as true embedded generation, supplying power to the local area. Only short connection distances to the grid will be needed.

The connection of the Kielder wind generation area will represent the most significant connection project, as it is both the largest and the most remote renewable generation area. Upgrading the existing lines running to Harker via Spadeadam is likely to be the most acceptable solution – although longer and more costly than other technically feasible alternatives, it avoids the National Park and Hadrian’s Wall.

There is an area in central Northumberland identified as suitable for small groups of wind turbines. We considered the possibility of establishing a new substation on the 400 kV grid interconnector in this area. To justify the cost of such a substation, at least 10 small wind farms would be required within a radius of about 10 km. An alternative, which we recommend for further study, would be to use the local 20 kV network to allow a more dispersed exploitation of this resource.

In modelling the grid to assess the connection of the new generation, different scenarios were considered representing approximately 25%, 50% and 100% implementation of the potential capacity. These were compared to a “no-renewables” scenario to separate the impact of renewables from other changes in the grid. Overall, the performance of the grid *improved* when renewables were added to the system:

- *Utilisation*. Several key circuits and transformers will experience reduced loading as local generation cancels out some imported power flows. The reduction in loading generally increases as more renewables are connected. Only the 400 kV circuits exporting power south out of the region are likely to experience significant loading increases.

- *Outages*. Lower loading will reduce overloads and improve voltage conditions in several locations. The increased loading on the 400 kV export network, however, may have the potential to cause an overload if an outage in the Norton-Osbaldwick line concentrates power flows through the Seal Sands-Lackenby line. In practice it is likely that in such an event generation would be constrained to reduce the overload.

- *Short-circuit fault levels*. There will be minimal effect on fault levels under all three renewable scenarios.

The study has not considered the potential for voltage stability issues that can occur when the network is connected to faults with asynchronous generation (e.g. wind). With the advent of modern technology such as Double Fed Induction Generation (DFIG), these issues can be managed on a project-by-project basis.

In summary, the connection of the renewables identified in the Regional Strategy is feasible with the grid as currently planned, and is in fact likely to provide some benefits to it. The significant area of new investment required will be for new lines connecting remote rural generation to the grid. The overall Strategy should include the routes for these connections as an integral part of the renewable generation areas, since they will be crucial in allowing the region to meet its renewables targets.

1. INTRODUCTION

1.1 Context

PB Power was commissioned by the Government Office for the North East to examine grid connections for renewable energy developments in the region. This forms part of the Regional Renewable Energy Strategy being managed by TNEI.

The purpose of the Strategy is to show how the Government's renewable energy targets can be met in the North East region, and to feed this data into the Regional Planning Guidance/Regional Spatial Strategy process.

1.2 Terms of reference

The terms of reference for the study were to:

1. Examine the current transmission and distribution grid in the region, including the impact of any planned improvements;
2. Consider the capacity of the grid to accept new generation in areas of interest for renewables;
3. Propose how additional renewable generation could be catered for.

Information on existing grid capacity, and the potential of capacity improvements, was required in a digital format for incorporation into the Regional Renewable Energy Strategy Geographic Information System (GIS).

1.3 Approach

The region covered by this study is the administrative area of the Government Office for the North East, although by its nature some consideration of electricity network in neighbouring areas was required. The analysis in this study was carried out using publicly available data on the transmission and distribution grids, specifically the Seven Year Statements (SYS) from the National Grid Company and the Long Term Development Statement (LTDS) from NEDL. Relevant data from neighbouring areas was taken from the United Utilities LTDS and the Scottish Power LTDS and SYS. These supplied the necessary data to build a model of the existing grid and its planned improvements through to 2007 (LTDS) and 2010 (SYS).

Areas of interest for renewable generation were supplied by TNEI, and were primarily derived from the initial results of the wider Strategy work. Expected levels and types of renewable generation within each area were agreed, and other forms of embedded generation with potential in the same areas were identified.

The identified generation was grouped into area "blocks", based on the most practical configuration with respect to the nearby grid. Identifying specific wind project locations was considered inappropriate for this study, so general wind areas were identified. Hydro and biomass projects have been placed at specific locations where potential sites are known.

The capability of the grid to accept these generation blocks was assessed against the model, based on low, medium and high generation scenarios. These simulated deployment of few, some and all of the potential generation projects respectively. Necessary connections and upgrades were then defined.

1.4 Report structure

This report contains 6 sections, including this introduction.

Section 2 outlines the levels and locations of renewable generation assumed in the study, along with allowances for other forms of embedded generation.

Section 3 describes the existing and planned transmission and distribution grid in the region.

Section 4 indicates how the grid can cater for the increased renewable generation, principally through new connections for the remote generating areas.

Section 5 describes the power system modelling studies

Section 6 presents our conclusions and recommendations.

2. RENEWABLES AND OTHER EMBEDDED GENERATION

2.1 Focus areas for renewables

While there is potential for renewable generation throughout the North East region, this study has focussed on areas with the greatest potential for actual projects to be developed. The areas of focus, and the levels and type of renewable generation, are those put forward in the overall Regional Strategy. In addition, informal discussions with developers revealed some further areas of interest and these have been included. The areas, projects and assumptions have been agreed with TNEI.

The map in Appendix A shows the areas of focus and the types of generation considered, and Table 2.1 below indicates the level of generating capacity allowed for in each area. Wind is the predominant technology, and the following assumptions have been used:

- Average turbine size of 2 MW;
- A small wind farm will consist of up to 5 turbines, giving a capacity of 10 MW;
- A medium sized wind farm will consist of up to 25 turbines, giving a capacity of 50 MW;
- Kielder provides the only area for very large-scale wind generation. A maximum capacity of 500 MW has been used, reflecting the level required to reach 20% renewable generation in the region by 2020[1]. Further discussion of Kielder is included in appendix B.

2.2 Other embedded generation

The potential for other embedded generation projects has been considered, and is shown in table 2.1. These will be relevant to this study where they may occur in the same area as renewables projects, and thus compete for available grid connection capacity. Specific embedded generation technologies considered were CHP, coalmine methane (CMM), landfill gas (LFG) and energy-from-waste (EfW). For each area of interest, an allowance was made for potential embedded generation using the following assumptions:

- CHP – small projects (up to 1 MW) such as community heating schemes, institutions;
- CMM – will occur where suitable former mines exist. Typical project size 2.5 MW;
- LFG – will occur where suitable landfills exist [2]. Typical project size 2.5 MW;

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[1] This represents the extra capacity required to move from 10% in 2010 to 20% in 2020, as identified by TNEI in the Regional Strategy.

[2] Sites identified from Environment Agency database

- EfW – a recent regional waste management study[3] calls for an increase in EfW capacity equivalent to approximately 75 MW of generation. A 20 MW allowance has been made in the more urban areas of the study.

The Riding Mill pumped storage scheme has also been included.

Table 2.1: Overall levels of embedded generation

Area	***Area Name***	***Renewable generation***	***Allowance for other embedded generation***
A	Berwick	2 x 50 MW wind	5 MW (CHP, CMM)
B	Alnwick	2 x 50 MW wind	5 MW (CHP, LFG)
C	Kielder	1 x 500 MW wind 1 x 3 MW hydro 1 x 10 MW biomass	None
D	Blyth	1 x 50 MW wind 1 x 20 MW offshore wind 1 x 5 MW biomass	30 MW (CHP, LFG, CMM, EfW)
E	Hexham	3 x 50 MW wind	20 MW (CHP, LFG, pumped storage)
F	Durham Upland Fringe	4 x 50 MW wind	10 MW (CHP, LFG)
G	Durham Coast	3 x 50 MW wind	30 MW (CHP, LFG, CMM, EfW)
H	Hartlepool	2 x 50 MW wind 1 x 10 MW wind	30 MW (CHP, LFG, EfW)
I	Teesdale	3 x 50 MW wind	5 MW (CHP, LFG)
J	Upper Teesdale	3 x 1 MW hydro	None
K	Tees Coast	1 x 75 MW offshore wind 1 x 30 MW biomass 1 x 10 MW wind	30 MW (CHP, LFG, CMM, EfW)

- Wind projects are identified in units of 10, 50 and 500 MW for convenience. Overall levels are likely to be achieved by various combinations of sizes.

As will be shown in section 3, the levels of non-renewable embedded generation do not make a significant difference to the overall results of this study, given their small size relative to the power flows through the grid in the region.

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[3] "Towards a Waste Management Strategy for the North East of England", ERM, Feb 2003, http://www.northeastassembly.gov.uk/publications/rws_final%20report.pdf

3. EXISTING AND PLANNED ELECTRICITY GRID IN NORTH EAST ENGLAND

In developing a computer-based model of the North East Grid for use in power system studies it is necessary to identify the relevant details of the connected generation, the forecast demand and the transmission and distribution system parameters and network configuration. The following section addresses each of these constituent parts of the North East Grid system.

3.1 Existing and planned generation

The demand for electrical energy in the United Kingdom is highest in the south east of England, whilst the bulk of generating capacity has been and still is sited in the Midlands, Northern England and Scotland. Consequently power flows continually in a general north - south direction from the Scottish borders to the main grid stations that supply the demand in the London area.

In North-east England sufficient generating capacity is installed to supply the local load and to supplement the power transmitted southwards over the Anglo-Scottish Interconnectors. Surplus power is then transmitted southwards over the NGC 400 kV transmission network to supply other load centres in Yorkshire, the Midlands and Southern England, being supplemented en route by the output from other power stations.

The recent retirement of Blyth power station has effectively left three major power stations operational in the region:

i) Teesside CCGT (1875 MW installed capacity), the largest CCGT power station in the United Kingdom,

ii) Hartlepool nuclear station (1202 MW installed capacity), and

iii) Lynemouth coal-fired station (420 MW installed capacity).

The Lynemouth station not only supplies the demand on the adjacent Alcan aluminium smelter site but also exports surplus electricity to the grid.

Bulk power is also imported into the region from Scotland at Stella West 400/275 kV grid station. In its Seven Year Statement[4], NGC has estimated that the imported power at Stella West will be maintained at between 1050 MW and 1200 MW at the time of system peak demand over the period 2003/04 to 2009/10. With the commissioning of the second Yorkshire line in 2003 (a 400 kV double circuit connection) the power imported over the Anglo-Scottish Interconnectors will be increased to 2200 MW. The power imported through Stella West will effectively be about one-half of the capacity of the Anglo-Scottish Interconnectors. The other half is directed southwards through Harker 400/275 kV grid

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[4] The development plans of the National Grid Company are published annually (with quarterly updates) in a document known as the Seven Year Statement.

station, located near Carlisle, and therefore flows outside the region. A 275 kV double circuit connection links Stella West and Blyth with Harker and limited power transfers are carried over this link with the bulk of the imported power from Scotland being transmitted southwards at Harker over the 400 kV transmission system. Over the period 2003/04 to 2009/10 the maximum power imported over the Anglo-Scottish Interconnectors is expected to remain at 2200 MW.

By 2006/07 a new CCGT station is scheduled to come into service at Seal Sands on Teesside with an installed capacity of 779 MW. This station will feed directly into the 400 kV transmission system between Lackenby and Norton at a new grid station on the Seal Sands site.

A new DC link with Statnett SF of Norway will also be established in 2006/07 to import up to 1320 MW[5] of power. The power from the link will be injected into a new 400 kV grid station at Hawthorn Pit, south of Sunderland.

Table 3.1 lists the installed generating capacity in North-east England over the period 2003/04 to 2009/10. The table includes the capacity assigned to power imported via interconnections with Scotland and Norway. The registered capacity figures quoted in Table 3.1 are based on information given in the 2003 Seven Year Statement published by the NGC.

The table shows the installed (i.e. registered) capacity, and the power generated or imported at each power source in our studies of the North-East Grid in 2003/04 and 2009/10. The figures used in the model are comparable with those presented in the Seven Year Statement system studies.

A limited amount of smaller generating plants are embedded in the local distribution network of Northern Electric Distribution Ltd (NEDL). These are almost exclusively associated with industrial plants in the Teesside area. Table 3.2 lists the amount of embedded generation connected to the NEDL distribution network over the period 2003/04 to 2009/10 as identified in the Seven Year Statement.

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[5] The DC link with Statnett SF of Norway is designed as a bi-directional interconnection for the transfer of up to 1320 MW between the two countries. Our studies have concentrated on establishing maximum power flows on the system and therefore we have restricted the analysis to studies with the DC link importing maximum power.

Table 3.1: Installed generating capacity in N.E. England (2003/04 to 2009/10) plus interconnector capacity

Power Source	Grid Connection Point	Registered capacity	2003/04 Generation (MW)	2009/10 Generation (MW)
Stella-Border import (East Coast Scottish interconnector)	Stella West 400 kV	-	1150	1150
Harker 400 kV import (West Coast Scottish interconnector)	Harker 400 kV	-	800	800
Harker 275 kV import (West Coast Scottish interconnector)	Harker 275 kV	-	250	250
Teesside	Greystones 275 kV	1875	1470	1470
Hartlepool	Hartlepool 275 kV	1202	1150	1150
Lynemouth (Alcan)	Alcan 132 kV	420	335	335
Seal Sands	Seal Sands 400 kV	779	-	635
Norway interconnector	Hawthorn Pit 400 kV	-	-	1320
	Total	4276	5155	7110

Table 3.2: Embedded generating capacity in N.E. England (2003/04 to 2009/10)

Power Source	Grid Connection Point	Registered capacity	Type	2003/04 Generation	2009/10 Generation
BASF	Saltholme	82.3	CHP	40	40
Phillips	Saltholme	80	CHP	50	50
Viking	Saltholme	52	Gas	0	0
Cleveland Incinerator	Norton	35	Waste	20	20
Northallerton	Norton	6.4	Diesel	4.5	4.5
Bran Sands	Lackenby	10	Waste Gas	10	10
Cleveland Potash	Lackenby	22.4	Gas	15	15
RVI	Stella North	8.5	CHP	8.5	8.5
	Total	296.6	-	148	148

3.2 Demand forecast for North-East England

The demand forecast produced by NGC in the 2003 Seven Year Statement for the period 2003/04 to 2009/10 has been correlated with the load forecast produced by NEDL in its Long Term Development Statement (which only covers the period to 2006/07) to derive a forecast of peak demand at bulk supply points across North-east England. Where there are differences between the NGC and NEDL forecasts, we have used NGC data and the NEDL data for substations directly relevant to the study, and allocated differences to non-relevant NEDL substations to minimise impact on the study results.

Table 3.3 shows the demand forecast at individual substations in 2003/04 and 2009/10. The forecast corresponds to the substation demand at the time of NGC's system peak demand. The table includes a number of NEDL substations to which renewable generation was connected in our studies.

The NGC demand forecast for North East England over the period 2003/4 to 2009/10 showed an annual growth rate of approximately one percent per annum. Therefore to derive the forecast for the additional NEDL substations in 2009/10 this rate has been applied to the 2006/07 forecast loads. Table 3.3 also includes an estimate of the 2019/20 load on the basis of an annual increase in demand of one percent. Consequently the peak demand in the region is expected to increase as follows:

i)	2002/03	3298 MW
ii)	2009/10	3585 MW
iii)	2019/20	3841 MW

Table 3.3: Summary of grid and primary substation peak demand (MW & MVAr)

Group	Substation	Bus name	Volts (kV)	PF	2002/03		2009/10		2019/20	
					MW	MVAr	MW	MVAr	MW	MVAr
NGC GRID	Fourstones	FOUR20	275	0.97	15	3.6	15	3.6	16.6	4.0
	Tynemouth	TYNE20	275	0.98	215.4	42.9	231	46.0	255.2	50.8
	South Shields	SSHI20	275	0.96	46.3	13.0	46.7	13.1	51.6	14.4
	West Boldon	WBOL20	275	0.99	256.9	36.2	262.3	37.0	289.7	40.9
	Offerton	OFFE20	275	0.96	61.1	17.1	65.6	18.4	72.5	20.3
	Tod Point	TODP20	275	0.98	372.0	74.0	436.0	86.8	481.6	95.8
	Saltcombe	SALH20	275	0.92	150.3	58.9	156.1	61.2	172.4	67.6
	Osbaldwick	OSBA40	400	0.95	248.6	77.6	282.3	88.1	311.8	97.4
		Total	-	-	1365.6	323.4	1495.0	354.2	1651.4	293.8
BLYTH 132 & 66	Blyth	BLYT61 / BLYT62	66	0.97	192.6	46.8	205.2	49.9	226.7	55.1
	Alcan	ALCA10	132	0.88	150.3	71.4	154.6	73.4	170.7	81.1
	Ulgham Rail	LINT1A / LINT1B	132	0.99	17.2	2.4	17.7	2.5	19.6	2.8
	Linton	LINT60	66	0.96	68.7	19.2	71.9	20.1	79.4	22.2
		Total	-	-	428.9	139.9	449.4	145.9	496.4	161.2
STELLA 132	Stella North	STEN11 / STEN12	132	0.96	266.6	74.6	300.6	84.2	332.0	93.0
	Stella South	STES11 / STES12	132	0.94	194.9	66.5	204.5	69.8	225.9	77.1
	Coalburns	COAL60	66	0.98	65.6	13.0	70.2	14.0	77.5	15.4
	Annfield	ANNF60	66	0.96	62.1	17.4	71.5	20.0	79.0	22.1
		Total	-	-	589.2	171.6	646.8	187.9	714.5	207.6
SPENNYMOOR 132/66	Spennymoor	SPEN11 / SPEN12	132	0.94	81.6	27.8	94.1	32.1	104.0	35.5
	Spennymoor	SPEN61 / SPEN62	66	0.96	113.8	31.9	132.7	37.2	146.6	41.0
	Toronto	TORO60	66	0.91	67.3	27.9	74.1	30.7	81.8	33.9
		Total	-	-	262.7	87.6	300.9	100.0	332.4	110.4
HAWTHORN 66	Hawthorn Pit	HAWP61 / HAWP62	66	0.96	115.6	32.4	128.3	35.9	141.7	39.7
HARTMOOR 66	Hartmoor	HARM61 / HARM62	66	0.97	98.4	23.9	107.5	26.1	119	28.9
LACKENBY 66	Lackenby	LACK61 / LACK62	66	0.99	223.3	31.5	235.6	33.2	260.2	36.7
NORTON 132	Norton	NORT11 / NORT12	132	0.95	314.9	98.3	344.2	107.5	380.2	118.7
	North Tees	NTEE60	66	0.97	148.3	36.1	159.4	38.8	176.1	42.8
		Total	-	-	463.2	134.4	503.6	146.2	556.3	161.5
HARKER 132	Harker	HARK40	400	0.98	788.0	156.8	1055.0	209.9	1055.0	209.9
	Harker	HARK11 / HARK12	132	0.92	293.4	115.0	320.3	125.5	353.9	138.7
	Spadeadam	SPAD1A / SPAD1B	132	0.91	15.2	6.3	15.8	6.5	17.4	7.2
		Total	-	-	1096.6	278.1	1391.1	342.0	1426.3	355.8
		GRAND TOTAL	-	-	4643.5	1198.8	5258.2	1345.4	5579.2	1366.8

It is evident from a comparison of the generating and interconnector capacity given in Tables 3.1 and 3.2 with the demand forecast in Table 3.3 in each of the above years, that even with no additional generating capacity installed in the region and the retirement of Lynemouth coal fired station between 2009/10 and 2019/20, that a substantial export of surplus power will be transmitted southwards from the region over this period. Table 3.4 compares the installed generating capacity, the power supplied from the Scottish and Norwegian interconnectors and the embedded generation with the forecast demand in the region.

The table assumes that the stations at Teesside, Hartlepool and Seal Sands will remain operational to beyond 2019/20 and assumes that no additional embedded generation is added to the system over the period to 2019/20. The interconnector capacity is based on what NGC estimate the power flow will be in 2003/04 and 2009/10 into Stella West from Eccles Grid Station in Scotland, plus that imported from Norway.

Table 3.4: Comparison of generating capacity, embedded generation, interconnector capacity and peak demand in North East England (2003/04 to 2019/20)

Year	2002/03	2009/10	2019/20
Installed generation capacity (MW)	3497	4276	3856
Installed interconnector capacity (MW)	1150	2470	2470
Embedded generation	297	297	297
Total generation capacity (MW)	4944	7043	6623
Peak demand (MW)	3298	3585	3841
Surplus Power for export (MW)	1646	3458	2782

3.3 The electricity grid in North East England

The transmission of bulk electrical power across the region is the responsibility of NGC, which owns and operates the 400/275 kV transmission system. The system essentially facilitates the transport of bulk power from the East Coast Anglo-Scottish Interconnector and the main North-east power stations to the 275/132 kV, 275/66 kV and 132/66 kV bulk supply point substations on the NEDL distribution system that service the main load centres in the region, whilst enabling surplus power of the order identified in Table 3.4 to be exported through the region to load centres in the south.

The distribution of electrical power across the region is the responsibility of NEDL which takes power from the grid supply point substations and distributes power at 132 kV, 66 kV 33 kV and at lower voltages to consumers throughout the region.

3.3.1 NGC transmission system

Figure 3.1 shows in outline the NGC transmission system in North-east England in 2003/04. The figure presents in geo-schematic form the main transmission supply routes at the 400 kV and 275 kV voltage levels.

The transmission network is essentially composed of the following main circuit elements:

- The double circuit 400 kV transmission line from Eccles in the Scottish Borders to Stella West 400/275 kV grid station (to the west of Newcastle upon Tyne) that delivers power across the East Coast Scottish Interconnector.

- Stella West is interconnected with the Grid station at Blyth on the Northumberland coast, the two main grid stations in the northern part of the region that provide supplies to the Tyneside conurbation. From these two stations 275 kV circuits are routed along the Tyne Valley to Harker grid station near Carlisle (which receives bulk power from the West Coast Anglo-Scottish Interconnector).

- Two 275 kV circuits are routed south from Stella to Norton on Teesside via Spennymoor.

- From Blyth two 275 kV circuits are also routed south to Teesside down the Durham coast. En route these circuits supply a number of grid stations and connect Hartlepool Power Station to the grid system.

- From Hartlepool the 275 kV circuits split with one circuit routed to Norton near Stockton-on-Tees and the other routed to Lackenby on the outskirts of Middlesbrough

- Teesside power station is connected into the 275 kV system at Lackenby

- The 400 kV system that supplies bulk power southwards from the region is routed from Lackenby and Norton grid stations on Teesside to Osbaldwick and Thornton 400 kV grid stations in the York area. A 400 kV circuit, however, interconnects Norton with Hawthorn Pit and is connected through a 400 / 275 kV step-down transformer at Hawthorn Pit to one of the two 275 kV circuits that are routed down the Durham coast.

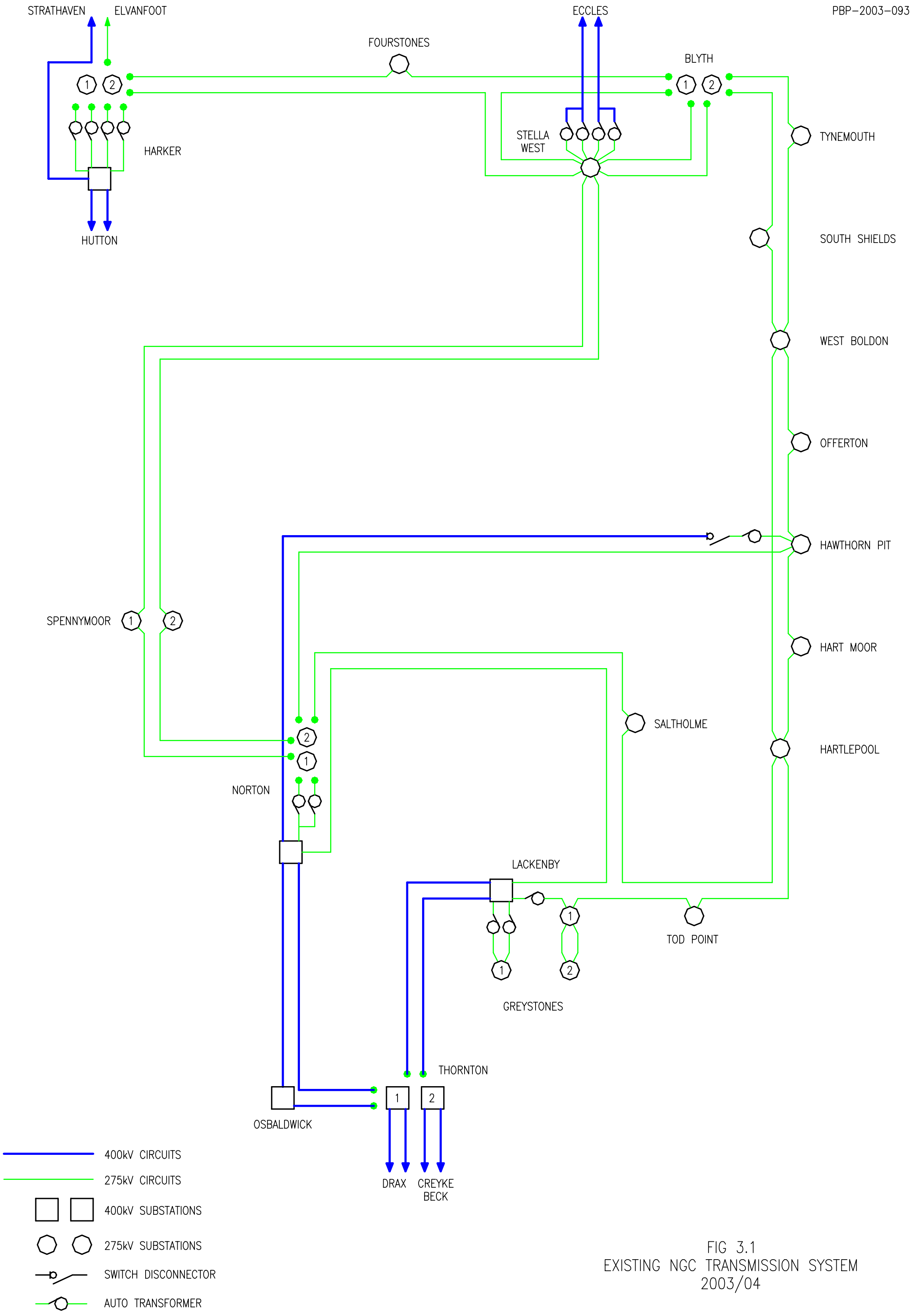

FIG 3.1
EXISTING NGC TRANSMISSION SYSTEM
2003/04

Figure 3.2 shows geo-schematically the planned system in 2009/10 with the principal modifications being those associated with the introduction of the new power station at Seal Sands on Teesside and the interconnector with Norway. The new power station and new receiver station are connected to the NGC system via new 400 kV substations at Seal Sands and Hawthorn Pit. The planned modifications to the NGC transmission system in the region over the period to 2009/10 are summarised below:

2003/04

a) The Norton – Thornton 400 kV circuit is to be routed through Osbaldwick 400 kV grid station.

b) The Hartlepool – Tod Point 275 kV circuit is to be upgraded over part of its length.

2005/06

a) Seal Sands power station will be commissioned and connected into the system by routing the existing Norton – Lackenby 400 kV circuit through Seal Sands.

b) The Norton 275 kV busbar will be run as a solid bus.

c) A 400 kV grid station will be established at Hawthorn Pit to receive the power imported over the Anglo-Norwegian interconnector. The existing 275 kV circuit between Norton and Hawthorn Pit will be replaced with a 400 kV circuit. This new circuit and the existing 400 kV circuit will be routed directly into the new grid station.

d) The existing Hartlepool – West Boldon 275 kV circuit will be routed through the new 400 kV substation at Hawthorn Pit via step-up and step-down 400/275 kV transformers.

There are also plans for a number of minor changes to system configuration associated with the status of busbars on the network to either control fault level or improve system operation. These were taken into account in our system model.

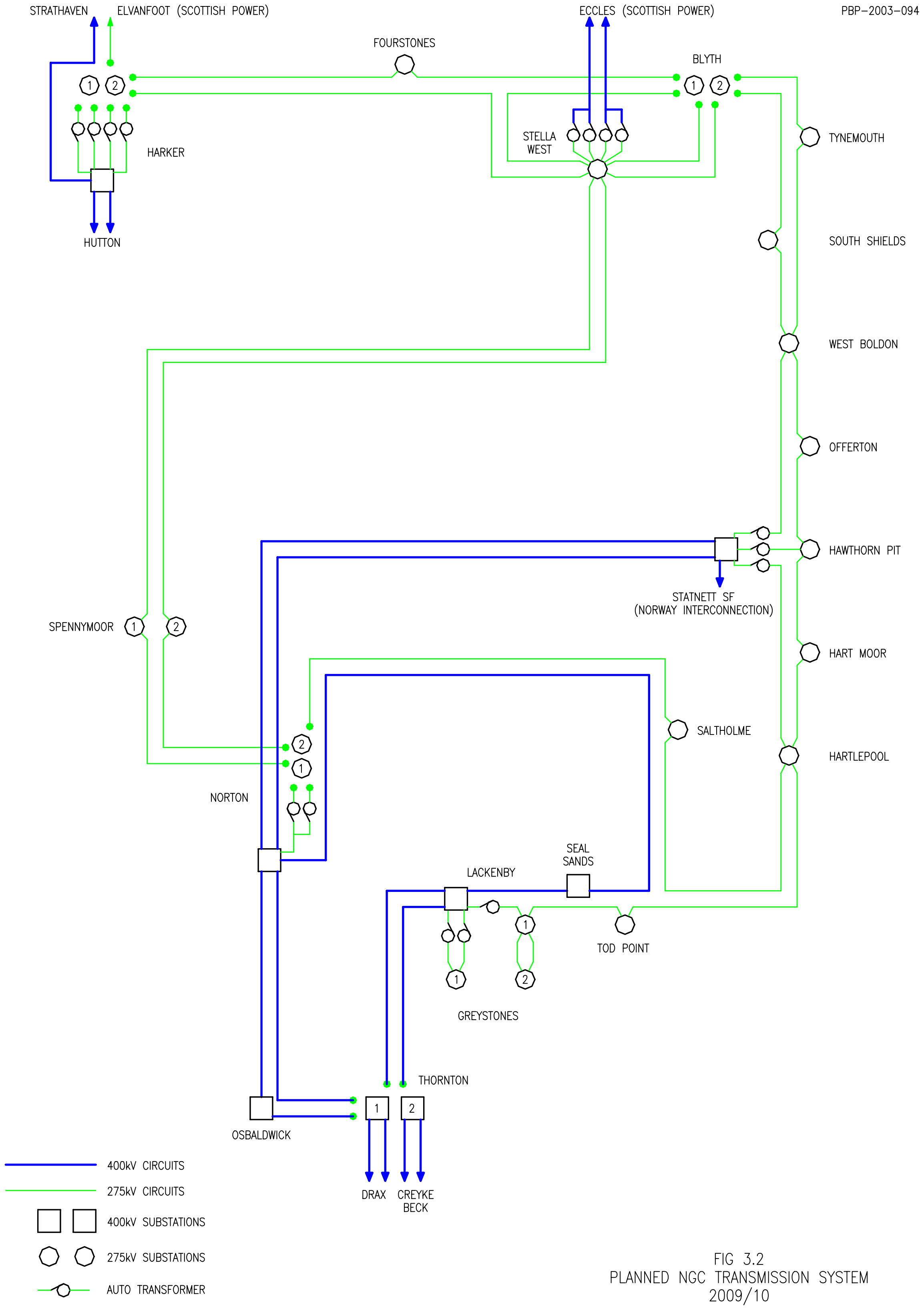

FIG 3.2
PLANNED NGC TRANSMISSION SYSTEM
2009/10

3.3.2 NEDL distribution system

The methodology for this study has been restricted to consideration of the NEDL 132 kV system and parts of the 66 kV distribution system, where it has been considered appropriate. Consequently only limited parts of the NEDL distribution system have been studied in any detail and these are associated with the connection of the new renewable generation to the grid system

Details of the NEDL distribution system were available from the NEDL Long Term Development Statement including a list of planned developments for the period to 2006/07. The developments that are of relevance to this study are summarised below:

2002[6]

a) A new 66/20 kV 40 MVA primary substation was planned for Consett to reinforce Annfield primary substation.

b) A new 275/20 kV grid station was planned for Fourstones to reinforce the supplies to the Hexham area.

c) The 66 kV conductors on the Linton – Denwick overhead line are age expired and were due for replacement.

2003

a) A new 33/20 kV 4 MVA package unit will be connected to the 33 kV line from Spadeadam.

2004

a) The 132 kV bulk oil switchgear at Norton will be replaced.

b) A third 400/132 kV transformer is required at Osbaldwick.

c) A third 275/132 kV transformer is required at Stella South to reinforce the supply from Stella West.

The majority of these system changes, whilst associated with areas represented in the detailed model, have negligible effect upon the modelling itself. It is interesting to note, however, that reinforcements are planned for the supply to Stella South and in the Annfield area, where the studies in section 5 have identified the need for system reinforcement to avoid overload and low voltage problems under outage conditions.

A map of the NGC transmission system and of relevant parts of the NEDL distribution system in Northumberland, Durham and North Yorkshire is presented in Appendix A.

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[6] These developments, that were scheduled for completion in 2002, have been assumed as completed in the results of the study.

Sections of the Scottish Power and United Utilities systems that offer the possibility for connection in the Berwick and Kielder areas are also shown.

4. CONNECTION OF RENEWABLES TO THE GRID

4.1 Connection of renewable generating schemes to the grid system

The thirty-two renewable generating schemes listed in Table 2.1 are distributed across the region from the Scottish border in the north to Teesside in the south and from offshore wind off the North Sea coast to small hydro schemes in the north Pennines and a large wind generation area around Kielder. These schemes, particularly for wind power, are not definitive proposals, but an indication of the level and scale of generation appropriate to each area, designed to assess the capabilities of the grid.

Examination of the location of each of the thirty-two schemes in relation to the North East Grid has led to the conclusion that the schemes can be formed into eleven distinct generation groups as presented in Table 4.1. For the purposes of this grid study, locations for wind farms have been chosen. This was done in order to be able to model the system and estimate the connection costs required, and does not imply that these locations are actually suitable for wind generation. They should be viewed as illustrative locations only.

Individual renewable generating schemes considered in the study fall into one of the following types:

- Small hydro schemes (from 1 MW to 3 MW)
- Small urban wind-farms (10 MW)
- Biomass schemes (from 5 MW to 30 MW)
- Medium size wind-farms (50 MW)
- Offshore wind-farms (20 MW and 75 MW)
- Large-scale wind area (up to 500 MW).

Of the schemes considered twenty-two have been assigned a generating capacity of at least 50 MW. These schemes are therefore of sufficient capacity to require connection at voltages of 66 kV or above (depending on their proximity to each other and to the grid) in order to ensure that the power generated can be injected efficiently into the grid system without contravening either thermal or voltage limits.

Table 4.1: Identification of renewable generation groups and distances from possible connection sites

Group	Scheme no.	Area	Approximate Location	Easting OS Grid Ref.	Northing OS Grid Ref.	Type	Max. MW	Nearest Grid Stn	Easting OS Grid Ref.	Northing OS Grid Ref.	Distance (km)	Nearest Grid Stn	Easting OS Grid Ref.	Northing OS Grid Ref.	Distance (km)	Nearest Grid Stn	Easting OS Grid Ref.	Northing OS Grid Ref.	Distance (km)
A	1	Berwick	Horncliffe	394	650	Wind (med.)	50	Eccles	380	642	16.1	Berwick	395	654	**4.1**				
	2	Berwick	Ladykirk	389	648	Wind (med.)	50	Eccles	380	642	10.8	Berwick	395	654	**8.5**				
						Total	100												
B	3	Alnwick	North Charlton	419	623	Wind (med.)	50	Denwick	421	616	**7.3**								
	5	Alnwick	Hebron	420	589	Wind (med.)	50	Linton	425	593	**6.4**								
						Total	100												
C	4	Kielder	Wainhope	367	595	Wind (Strat.)	500	Harker	338	561	44.7	Eccles	380	642	48.8	Fourstones	390	569	**34.7**
	6	Kielder	Kielder	371	587	Hydro*	3	Spadeadam	361	570	19.7	Eccles	380	642	55.7	Fourstones	390	569	**26.2**
	7	Kielder	Kielder	371	587	Biomass	10	Spadeadam	361	570	19.7	Eccles	380	642	55.7	Fourstones	390	569	**26.2**
						Total	513												
D	8	Blyth	East Sleekburn	428	584	Wind (med.)	50	Blyth	430	583	**2.2**								
	9	Blyth	Blyth	430	582	Biomass	5	Blyth	430	583	**1.0**								
	10	Blyth	Blyth	431	583	Offshore wind	20	Blyth	430	583	**1.0**								
						Total	75												
E	11	Hexham	Cowden	392	579	Wind (med.)	50	Fourstones	390	569	**10.2**	Coalburns	412	561	26.9				
	12	Hexham	Colwell	395	575	Wind (med.)	50	Fourstones	390	569	**7.8**	Coalburns	412	561	22.0				
	13	Hexham	Healey	401	558	Wind (med.)	50	Fourstones	390	569	**15.6**	Coalburns	412	561	11.4				
						Total	150												
F	14	Durham Upland Fringe	Consett	411	549	Wind (med.)	50	Tee Point 'A'	415	551	**4.5**	Annfield	417	551	6.3	Toronto	419	533	**17.9**
	15	Durham Upland Fringe	Butsfield	411	546	Wind (med.)	50	-	411	549	**4.5**	Annfield	417	551	7.8	Toronto	419	533	**15.3**
	28	Durham Upland Fringe	Tow Law	415	541	Wind (med.)	50	Tee Point 'B'	420	542	**5.1**	Annfield	417	551	10.2	Toronto	419	533	**8.9**
	29	Durham Upland Fringe	Satley	412	543	Wind (med.)	50	-	412	543	**8.1**	Annfield	417	551	9.4	Toronto	419	533	**12.2**
						Total	200												

Note: Distances quoted are point-to-point.

Table 4.1 (continued): Identification of renewable generation groups and distances from possible connection sites

Group	Scheme no.	Area	Approximate Location	Easting OS Grid Ref.	Northing OS Grid Ref.	Type	Max. MW	Nearest Grid Stn	Easting OS Grid Ref.	Northing OS Grid Ref.	Distance (km)
G	16	Durham Coast	Hetton-le-hole	436	547	Wind (med.)	50	Hawthorn Pit	438	546	2.2
	31	Durham Coast	Shotton Colliery	441	541	Wind (med.)	50	Hawthorn Pit	438	546	5.8
	32	Durham Coast	Murton	440	547	Wind (med.)	50	Hawthorn Pit	438	546	2.2
						Total	150				
H	19	Hartlepool	Hutton Henry	443	536	Wind (med.)	50	Hartmoor	445	535	2.2
	20	Hartlepool	Blackhall Rocks	447	537	Wind (med.)	50	Hartmoor	445	535	2.8
	24	Hartlepool	Hartlepool	452	532	Wind (small urban)	10	Hartmoor	445	535	7.6
						Total	110				
I	18	Teesdale	Hamsterley	411	531	Wind (med.)	50	Toronto	419	533	8.2
	23	Teesdale	Bowes	402	515	Wind (med.)	50	Harmire Bridge	406	519	5.7
	30	Teesdale	Heighington	425	522	Wind (med.)	50	Toronto	419	533	12.5
						Total	150				
J	17	Upper Teesdale	Cow Green	381	529	Hydro	1				
	21	Upper Teesdale	Selset res.	393	521	Hydro	1				
	22	Upper Teesdale	Balderhead res.	397	519	Hydro	1				
						Total	3				
K	25	Tees Coast	Eston	454	520	Wind (small urban)	10	Lackenby	456	521	2.2
	26	Tees Coast	Teesmouth	455	525	Biomass	30	Lackenby	456	521	4.1
	27	Tees Coast	Tees	458	526	Offshore wind	75	Lackenby	456	521	5.4
						Total	115				
						GRAND TOTAL	1666				

Note: Distances quoted are point-to-point.
* in addition to existing 6 MW
*** Quotes 66/20 kV tx's, but no on drg.*

The power generated from a wind turbine is variable and under windless conditions the wind-farm will not generate power. Since the probability of windless conditions is much higher than the probability of a fault on the circuit between the wind-farm and the connection point on the grid system, the provision of a double circuit connection to maintain production under a single circuit outage cannot be justified on economic grounds.

However, an exception to this general principle has been made with the connection of 500 MW of wind capacity from Kielder to the 275 kV grid between Stella West and Harker (see Group C below).

A map of the transmission system and relevant parts of the distribution system in North-east England is presented in Appendix A that also identifies the location of each of the thirty-two renewable generating schemes and the eleven generation groups. Connection routes from the generation to the grid are shown, and section 4.2 below should be read in conjunction with this map.

4.2 Connection arrangements for generation groups

The grouping together of individual schemes and identification of the preferred grid connection point is described briefly below. The description establishes how the North-East Grid system model established from NGC and NEDL data for the years 2003/04 and 2009/10 has been extended to incorporate the full potential of renewable generation schemes identified in Table 2.1.

Group A. Two medium-size wind-farms located in the Scottish borders would have a joint capacity of 100 MW and will require connection to the grid system at 66 kV or above. In this area, however, the nearest 66 kV supply point on the NEDL system is Denwick, about 45 km away. The Scottish Power grid, however, has a 132/33 kV substation in the vicinity, i.e. Berwick Grid. The substation at Berwick Grid is supplied from Eccles 400/132 kV grid station that also supplies power to Stella West through the East Coast Anglo-Scottish Interconnector. The preferred supply arrangement for the connection of the Group A schemes is therefore via a 132 kV overhead line to Berwick Grid, probably a single line connecting both schemes. The two schemes when operating at full output should then be able to supply the demand previously supplied from Berwick Grid and feed surplus power back into the Scottish Power system at Eccles, thus reversing the direction of power flow through the 132 kV circuits between Eccles and Berwick Grid.

Group B. Two medium-size wind-farms in the broader Alnwick area would each be each located relatively close to substations connected to the NEDL 66 kV network, i.e. at Denwick and Linton respectively.

Whilst there are concerns[7] over the capability of the NEDL standard conductor size, i.e. “lynx” (aluminium conductor steel reinforced) conductor, to carry 50 MW at 66 kV, the 66 kV

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[7] Engineering Recommendation P27 “Current rating guide for HV overhead lines operating in the UK distribution system” quotes a summer rating of 433 A for Lynx for a design core temperature of 50’C. Under windy conditions this will increase significantly.

option is preferable to 132 kV which would require a major upgrade of both Linton and Denwick substations and replacement of the existing 66 kV Linton-Denwick overhead line with a new 132 kV double circuit line. The 66 kV option to radially connect the two wind-farms to the grid at Linton and Denwick respectively is preferred (although in practice it may be necessary to either use a higher rated conductor, possibly an all aluminium alloy conductor) or accept a reduced installed capacity of 40 MW.

When the northern scheme (no. 3) is operational the effect it will have on the NEDL system will be to supply local load at Denwick and Warkworth, thereby significantly reducing the demand on the 66 kV double circuit line between Linton and Denwick. The southern scheme (no. 5) will have a similar effect on the power flow through the Blyth – Linton 132 kV feeders, as it will supply the local demand at Linton and Ulgham Rail. Any remaining surplus will then be injected back into the system through the Blyth - Linton 132 kV double circuit line.

Group C. Major wind-farm development is being considered for the area around Kielder reservoir. This is a key development in terms of the overall Regional Strategy. The scheme under consideration is planned to generate up to 500 MW at full output. The connection of a 500 MW power station to the North East Grid will have to be at either 275 kV or 400 kV to limit the current through the system to a level that ensures an efficient connection arrangement that avoids the need for multiple circuits from the wind-farm to the nearest grid substation.

Three options have been considered for connection of the 500 MW of wind capacity at Kielder, assuming a nominal connection point north of the lake:

a) Connection to NGC's Harker 400/275/132 kV grid station along the existing route that links Harker with Kielder at 132 kV and 33 kV [8] via Spadeadam. The distance involved with this option is approximately 50 km.

b) Connection to Scottish Power's Eccles 400/132 kV grid station, near Greenlaw in the Borders district. This is also about 50 km, but would require the planning of a new route.

c) Connection to Fourstones 275 kV grid station, near Hexham, a distance of 35 km.

The preferred option from a technical and economic viewpoint is option c) which involves a shorter circuit length and can facilitate connection at 275 kV, rather than 400 kV. It would, however, require a new connection line crossing the Northumberland National Park.

In studying option c) the connection arrangement has been designed with a double circuit connection between the Kielder wind-farm and Fourstones. Each circuit should be designed under normal operation to carry 250 MW at full output. Strictly, to satisfy the NGC Security Standards, the 500 MW scheme should be provided with a secure connection to the NGC transmission system (i.e. giving 100 percent redundancy with each circuit rated to carry 500

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[8] The 132 kV double circuit line from Harker to Spadeadam is owned by United Utilities. A 33kV single circuit line owned by NEDL links Kielder and Spadeadam.

MW). This could increase the connection costs significantly and some relaxation of the security requirements, given the variable nature of the scheme's output, may be considered appropriate for this strategically important scheme. This will need to be clarified as the details of any generation scheme at Kielder are defined.

The double circuit arrangement was chosen on the basis that the connection of 500MW of generated power at Fourstones to a single 275 kV circuit could lead to imbalance between the power flows on the two 275 kV circuits between Blyth/Stella West and Harker, only one of which is currently routed through Fourstones 275 kV grid station. A more balanced arrangement for Fourstones that would give increased flexibility and security of supply in the event of the 500 MW wind-farm proceeding would require the routing of the Blyth-Harker 275 kV circuit through Fourstones. With the facility to split the 275 kV busbar at Fourstones, 250 MW of wind power could be injected into the 275 kV bus on each side of the split to balance the power flows on the two east – west 275 kV circuits [9].

Two relatively minor renewable schemes are also included in Group C; a 10MW biomass scheme at Kielder and an upgrading of the existing Kielder hydro station to increase its output by a further 3 MW. The two schemes at full output will provide an additional 13 MW. The hydro station is connected to the NEDL network at Kielder and the biomass scheme should also be connected locally. The two schemes would be available to supply the local load and export surplus power back to the grid via Spadeadam and Harker. However, the capacity of the single circuit Spadeadam-Kielder connection is constrained by the rating of the 33/11 kV 7.5 MVA transformers at each end of the line, whilst the 33 kV line is rated at 240 A (or 13.7 MVA). Whilst the upgrade of the hydro station would be likely to increase the power exported to the grid over the existing connection without causing the transformers to be overloaded, connection of the Biomass scheme would require the 7.5 MVA transformers to be replaced by higher rated transformers or at least reinforced with additional 7.5 MVA or 10 MVA transformers at each end of the line. Alternatively the biomass scheme could be linked into the connection arrangement for the 500 MW scheme, but for the purpose of our study we have opted for connecting the biomass scheme via Spadeadam. The size of the biomass scheme could also be reduced to allow the existing transformers to be used.

Group D. The Group D generation consists of a 50 MW onshore wind-farm, a 20 MW offshore wind-farm and a 5 MW biomass scheme. The three schemes are all in the Blyth area where there is a strong 66 kV network and the local load in 2003/04 will be in the region of 200 MW. Consequently the most practical arrangement for connection of the three schemes that form Group D generation is as embedded generation and our studies have proceeded on that basis.

Group E. Three 50 MW wind-farms located in the broader Hexham area have been assumed, two north of the Tyne and east of the A68, and one south of the river in the Slaley area. These would all be located within 10 - 20 km of Fourstones 275 kV grid station respectively. The northern schemes are much closer to Fourstones than any other point on

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[9] To further support the possibility that the Stella West – Harker 275 kV circuit should be routed through Fourstones this report also proposes connection of output (100 MW) from the Group E generating schemes to Fourstones grid station.

the grid, but their combined output of 100 MW is suited to a connection at 132 kV rather than 275 kV. The development of a new 275/132 kV grid station at Fourstones to accept the aggregated output of 600 MW from the wind generation from these schemes plus Kielder in Group C would provide a suitable connection point to the North East Grid, accounting for over one-third of the total renewable capacity under consideration.

The southern scheme is also close to Coalburns, and connection to the 132/66 kV 2x90 MVA substation at 66 kV or even to one of the incoming 132 kV circuits from Stella West would be an alternative to a connection to Fourstones. In this case scheme output could supply a substantial portion of the Coalburns load that was estimated at 66 MW at the time of the 2002/03 peak.

Group F. In the area between Consett and Tow Law on the Durham upland fringe the development of four 50 MW wind-farms would have a combined capacity of 200 MW at full output. The four schemes are located within 15 km of Annfield 132/66 kV substation, although the southern schemes are potentially closer to the Toronto 132/66 kV substation. A better option, however, is the double circuit 275 kV line from Stella West to Spennymoor grid station that is routed through the area to the south west of Annfield substation. This follows a route that takes it within 10 km of all four schemes.

Connection of the four schemes with two to each 275 kV line is considered the most practical and balanced connection arrangement, with the two northern wind-farms connected to one of the circuits as it passes through the Consett area, and the southern wind-farms connected to the other 275kV circuit at a point nearer to Esh Winning. The power from the four schemes will then supplement the existing power flow through the Stella West – Spennymoor circuits as it flows to Norton grid station and then southwards away from the region.

Group G. The three 50 MW wind-farms in Group G are all located close to Hawthorn Pit 275 kV grid station. The load on the grid station was 116 MW at system peak in 2002/03 and the grid station supplies a number of 66 kV primary substations in the Seaham and Peterlee areas. The most practical arrangement for this generation group is to consider it as connected to the 66 kV system and therefore embedded within the NEDL distribution system supplied from Hawthorn Pit grid station.

Group H. Two 50 MW wind-farms in this area would be located within 5 km of Hartmoor 275 kV grid station where the demand at the time of the 2002/03 system peak was 98 MW. The small urban 10 MW wind-farm at Hartlepool that is also included in Group H is likely to be located further away towards the south of the town. The NEDL 66 kV distribution system in the area should be suitable for the connection of these schemes and the most practical arrangement for the Group H renewables is to consider them as embedded within the 66 kV system supplied from Hawthorn Pit. At full output the schemes should be able to supply the demand in the Hartlepool area with surplus power available for export to the grid.

Group I. There are three 50 MW wind-farms in this generation group in South Durham. The western schemes are located nearest to Harmire Bridge 66 kV and Toronto 132/66 kV substations respectively, while the one in the Newton Aycliffe area is much closer to Darlington and Newton Aycliffe where there is a strong NEDL distribution system in place.

Consequently the best arrangement for the western schemes is considered to be respective connections at 66 kV to the Harmire Bridge and Toronto substations, whilst the Newton Aycliffe wind-farm is considered as embedded within the distribution system supplied from Norton 400/275 kV grid station from which the Darlington area obtains the bulk of its electricity supplies.

Group J. Three small hydro developments in Upper Teesdale at the Cow Green, Selset and Balderhead reservoirs that are proposed to deliver 1 MW each are considered too small and too remote from the 66 kV network to justify their connection other than as embedded on the local 11 kV network at these locations. For the purpose of the study the Group J generation has effectively been ignored, as it amounts to less than 0.2 percent of the total potential renewable capacity in the region.

Group K. The generation connected in Group K is a mixture of offshore wind (75 MW), Biomass (30 MW) and a small urban wind-farm (10 MW). The three schemes are all likely to be connected to the NEDL distribution system at Lackenby, to the south of Middlesbrough, where the demand on the 400/275 kV grid station at 2002/03 system peak was 223 MW. There is a strong 66 kV network in the Lackenby area and for the purposes of our study the Group K renewables have been considered as embedded in the NEDL distribution system to effectively reduce the demand on the grid station when they are operational.

4.3 Alternative arrangement for connection of Group C generation

In section 4.2 we identified a 275 kV double circuit connection for the 500 MW of wind generation at Kielder, to the Fourstones grid station near Hexham as the preferred technical and economic arrangement. However, a direct route to Fourstones along the course of the North Tyne would involve the construction of a 275 kV transmission line through the Northumberland National Park and such a development would be likely to have a significant visual impact.

An alternative arrangement would be to route the 275 kV line along the route taken by the existing 33 kV line from Kielder to Spadeadam, and then install a new line running south to connect with the 275 kV lines between Harker and Fourstones at a point west of Haltwhistle. The result of our studies undertaken with Group C generation connected into Fourstones would still be applicable for this alternative connection. The connection to the 275 kV lines could conceivably be based on a simple tee-off arrangement that would produce some cost savings in comparison with the Fourstones arrangement. While avoiding the National Park, this option would still require a crossing of Hadrian’s Wall to reach the existing 275 kV route, with the attendant concerns over visual and other impacts that this would entail.

As a final point to note, the connection of Group E generation (100 MW at full output) to Fourstones by a 132 kV single circuit line and 275/132 kV 120 MVA transformer would still be valid if the Group C generation was routed to a connection point west of Haltwhistle.

However, in this case it would probably not be necessary to route the Blyth – Harker circuit (that currently is routed past Fourstones) into the grid station.

4.4 Estimated connection cost of renewable generating schemes

Table 4.2 shows the estimated cost of the connection arrangement for each renewable generation group identified in Table 4.1. The estimated cost is based on unit costs for switchgear, transformers, overhead lines and cables purchased in the UK by electricity companies. The costs were available in-house from recent studies and cover the cost of equipment and material from the connection point to the overhead line (or submarine cable) at the wind-farm to and including the switchgear at the point of connection to the grid station. The cost of the individual wind-farm electrical system is not included in Table 4.2. It should be noted that these costs are based on the illustrative locations chosen for generation in each area, and will vary as actual locations come forward.

The cost of connecting the Kielder wind area in Group C to Fourstones is estimated at £13.7 million. The other 275 kV arrangement involving the connection of the four Durham Moors Group F wind-farms to the Stella West – Spennymoor 275 kV overhead line has an estimated connection cost of £6 million. The remaining generation groups have connections costs of between £0.5 million and £1.5 million. The cost of connecting all thirty-two schemes to the grid is estimated at about £30.2 million, but the cost of the supply arrangement at the wind-farm itself would need to be added to this cost to derive the total cost.

Table 4.3 shows the cost of an alternative connection route for the Kielder wind capacity, following existing routes to Spadeadam and Harker. Due to the distance involved and the need to replace all the existing poles and towers to upgrade the route to 275 kV, this connection would cost an estimated £27.9 million.

These tables also give an indication of the minimum generating capacity required to justify such connections, assuming that projects are able to spend a maximum of 10% of the total capital cost on building the connection, and that new generation projects bear the full cost of the new connection.

It is clear that for most areas the projected capacity is well in excess of that needed to justify the connection. Only the Kielder route to Harker shown in table 4.3 has a minimum capacity greater than 50% of the projected capacity. Should the actual capacity be lower than the minimum identified here, the cost of the grid connection may be prohibitive and prevent the project going ahead. Lower generating capacity may, however, reduce the voltage level required and thus reduce the connection costs.

We have made an approximate analysis of the generation limits for different voltages, based on use of NEDL’s standard conductor sizes:

Level of generation	***Connection voltage***
< 50 MW	66 kV
50 – 125 MW	132 kV
> 125 MW	275 kV

This suggests that there is likely to be a range of deployed capacity at Kielder where a 275 kV connection would be required, but the capacity would be insufficient to justify the cost of the connection. This range will depend on the route chosen – it would be 125-183 MW for the Fourstones route, and 125-372 MW for the Harker route. This should be taken into account when considering the overall capacity available in the Kielder area. Note that there are likely to be technical solutions to allow higher capacity to be connected at 132 kV (e.g. the use of thicker conductors) that would raise the lower limit of the range.

Table 4.2: Summary of renewable scheme connection costs to North-East Grid

Group	Scheme Nos.	Area	Type of scheme	Total capacity (MW)	Grid connection point	Connection voltage (kV)	Total cost (£k)	Min scheme size (MW)*
A	1, 2	Berwick	Wind (med.)	100	Berwick Grid	132	**1226**	**16**
B	3, 5	Alnwick	Wind (med.)	100	Linton & Denwick prys	66	**977**	**13**
C	4	Kielder	Wind (large)	500	Fourstones	275	**13700**	**183**
	6,7	Kielder	Biomass & Hydro	13	Spadeadam	33	**350**	**5**
D	8, 9, 10	Blyth	Wind (med.), offshore & biomass	75	Blyth (embedded)	66	**1080**	**14**
E	11, 12	Hexham	Wind (med.)	100	Fourstones	132	**2862**	**38**
	13	Hexham	Wind (med.)	50	Coalburns	66	**633**	**8**
F	14, 15, 28, 29	Durham Upland Fringe	Wind (med.)	200	Stella West-Spennymoor tee offs	275	**5965**	**80**
G	16, 31, 32	Durham Coast	Wind (med.)	150	Hawthorn Pit (embedded)	66	**630**	**8**
H	19, 20, 24	Hartlepool	Wind (medium & small)	110	Hartmoor (embedded)	66	**630**	**8**
I	18, 23	Teesdale	Wind (med.)	100	Toronto & Harmire Bridge	66	**866**	**12**
	30	Teesdale	Wind (med.)	50	Norton (Embedded)	66	**210**	**3**
J	17, 21, 22	Upper Teesdale	Small hydro	3	-	-	-	-
K	25, 26, 27	Tees Coast	Offshore wind, Biomass & small wind	115	Lackenby (Embedded)	66	**1080**	**14**
						GRAND TOTAL (£K)	**30208**	

Table 4.3: Cost based on alternative routing of Kielder wind connection to Harker Grid Station

Group	Scheme Nos.	Area	Type of scheme	Total capacity (MW)	Grid connection point	Connection voltage (kV)	Total cost (£k)	Min scheme size (MW)*
C (Alt)	4	Kielder	Wind (large)	500	Harker	275	**27901**	**372**
						GRAND TOTAL (£K)	**44409**	

*** Assuming a capital cost of £750/kW, and that connection costs can represent a maximum of 10% of total capital**

5. POWER SYSTEM STUDIES

5.1 System model and methodology

A model of the existing North East Electricity Grid was established using an industry standard power system analysis software package, PSS/E [10]. The package enables a mathematical model of the grid to be established for the purpose of undertaking steady state analysis of the supply system, with the network configuration represented in the standard single line diagram form. Classical models for the main power system components, i.e. generators, transformers, overhead lines, cables and system loads, have been used to construct the overall system model using data presented in the NGC Seven Year Statement and in the Long Term Development Statements of NEDL, Scottish Power and United Utilities.

A model of the 2003/04 North East Grid (i.e. the existing grid) was developed initially for validation purposes to ensure that a reasonable correlation exists between the power flow and short circuit study results presented in NGC's Seven Year Statement and the results obtained from studies using the new model.

Modifications planned to the NGC and NEDL networks over the period 2003/04 to 2009/10 that were identified in the respective Seven Year and Long Term Development Statements of the two companies were then incorporated into the model alongside changes to system generation, interconnection arrangements and system demand to produce a model of the 2009/10 North East Grid. This model being consistent with that studied by NGC in its Seven Year Statement. System studies with the new 2009/10 model were then undertaken to compare the results with those presented in the NGC Seven Year Statement. This "base case" model of the 2009/10 grid relates to system conditions with none of the renewable generating schemes identified in Table 2.1 in service.

In our study of the impact of renewable generation on the grid we have considered three scenarios (or four if we regards the "base case" as a "do nothing" option). These are defined as:

i) **minimum renewable scenario** based on about 25% of possible capacity identified in Table 2.1 being installed,

ii) **moderate renewable scenario** based on about 50% of possible capacity being installed,

iii) **maximum renewable scenario** based on all of the renewable schemes identified being installed.

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[10] The PSS/E software was developed and is marketed by Power Technologies Inc., and is used extensively by Regional Electricity Companies in the UK. Parsons Brinckerhoff has a number of licences for the software and has used it on numerous power system studies since the mid-nineties.

In developing the generating capacity associated with the minimum and moderate renewable scenarios we have examined the potential capacity assigned to the various schemes in each generation group. For instances where there are, say, three 50 MW wind-farms in a group (such as in Groups E and G) the minimum scenario has assumed that only one scheme will proceed, the moderate scenario has assumed two schemes will proceed and the maximum scenario that all three schemes will be developed. Table 5.1 identifies the level of installed capacity in each generation group for each scenario in our study of the 2009/10 system.

In practice the output of the wind-farms will be variable and for most of the time the output from a scheme will be below its rated output. Additionally the output from the twenty-five wind-farms that are included in Table 2.1 will vary from place to place at any point in time since the wind speed will vary across the region, such that high wind speeds in the Kielder area that drive the 500 MW wind-farm to full output may be much lower along the coast, affecting groups B, D, G, H and K that account for another 515 MW of installed capacity. It is clear that almost an infinite number of combinations exist for the level of generated power from each of the twenty-five wind-farm schemes, which makes a study based on this approach impractical.

A scenario based on each scheme delivering full output simultaneously would be very unlikely to occur in practice and a coincidence factor can logically be applied to each generated output for study purposes. However, the object of the study is to determine the effect on the grid of the connection of the renewables and because of the limited timescale to undertake the work it was decided that more value would be obtained from studying system conditions with the renewable schemes each operating at full output. It can also be argued that the three scenarios may be regarded as undertaking the analysis with three different coincidence factors (i.e. equivalent to coincidence factors of 100%, 50% and 25%[11]).

An aspiration of the Government's energy strategy is to deliver 20% of the country's energy from renewable generation by 2019/20. Ideally a study of the grid performance in 2019/20 would provide the best indication of the effect of renewables on the local grid. However, NGC's long-term development plans that are available in the public domain only cover the period to 2009/10 and NEDL's only cover up to 2006/07. At this stage it is therefore impossible to estimate what changes will be made to the North East Grid between 2009/10 and 2019/20, or to the existing and future conventional power stations that are or will be connected to the grid during that period. The position is a little more predictable with regard to the demand forecast, with the demand increasing historically by about one percent per annum in recent years and we can reasonably expect this trend to continue over the ten-year period to 2019/20. In effect this will add only an additional 250 MW to the 2009/10 peak demand. On that basis it is reasonable to use the 2009/10 system models as a guide to system performance in 2019/20 with the renewable generation in service.

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[11] The 50% and 25% coincidence factors are approximate figures only.

Table 5.1: Installed capacity of renewable generation in each generation group with the three options

Generation Group	Potential schemes (n x MW)	Installed capacity Min scenario (MW)	Installed capacity Mod scenario (MW)	Installed capacity Max scenario (MW)
A	2x50	1x50	1x50	2x50
B	2x50	1x50	1x50	2x50
C	1x500 1x10, 1x3	1x10, 1x3	1x250, 1x10, 1x3	1x500, 1x10, 1x3
D	1x50, 1x20 & 1x5	1x20	1x20, 1x5	1x50, 1x20, 1x5
E	3x50	1x50	2x50	3x50
F	4x50	1x50	2x50	4x50
G	3x50	1x50	2x50	3x50
H	2x50, 1x10	1x10	1x50, 1x10	2x50, 1x10
I	3x50	1x50	2x50	3x50
J	3x1	-	-	-
K	1x75, 1x30, 1x10	1x30	1x30, 1x10	1x75, 1x30, 1x10
Total	**1666**	**373**	**888**	**1663**

5.2 Scope of system studies

The power system analysis considered relevant to this study of grid connections for renewable generation covers basic load flow and short circuit analysis. The studies are undertaken to identify the following critical aspects of system performance:

Load Flow studies. These are used to determine real and reactive power flow through each component on the network and therefore the level to which each component (whether overhead line, transformer or generator) is loaded on the network. In this way equipment overloads can be identified. The studies also determine the output from each generator or power source and voltage levels across the network. Load flow studies of normal and outage conditions are used to confirm that the system is compliant with its statutory obligations for maintaining system voltages within specified limits. The outage studies are undertaken to confirm that the system is compliant with the security of supply standards that are a condition of the transmission and distribution company operating licences.

Short circuit studies. These are used to determine maximum 3-phase short circuit fault levels across the network in order to confirm that the switchgear is adequately rated when all plant and circuits are in service with the system operating in its normal configuration. The studies are used to determine the 3-phase r.m.s. symmetrical break current, for comparison with the identified switchgear rating at each 400 kV, 275 kV, 132 kV and a selection of relevant 66 kV busbars on the North East Grid.

The analysis of each main case (i.e. the 2003/04 validation case and the four renewable generation scenarios in 2009/10) has covered the following studies:

a) Base Case load flow study at system peak demand with all plant and circuits available

b) Contingency studies of single circuit outage conditions at system peak demand

c) Double circuit outage conditions at system peak demand

d) Maximum 3-phase short circuit fault levels (with all plant and circuits available).

In examining system outage conditions the studies have examined the loss of a single transmission circuit outage (i.e. an n-1 case) and the outage of a double circuit overhead line. These outage cases are consistent with the most common outage cases specified in NGC Security and Quality of Supply Standard (issue 2) for which the system should remain intact and within defined voltage and thermal limits.

It should be noted here that although the following studies have identified a number of weaknesses in the performance of the NEDL system in 2009/10, the system model used was based on the NEDL Long Term Development Statement, which only identifies NEDL system plans up to 2006/07. In practice we would expect NEDL to have put in place by 2009/10 measures to avoid most, if not all, of the problems identified here[12].

5.3 Existing system performance (2003/04)

The 2003/04 system studies serve as a validation case for the North East Grid model. There are some differences from the 2003/04 peak load flow study presented in NGC's Seven Year Statement, essentially due to changes in the level of the power generated from Hartlepool Power Station and some re-distribution of loads to enable parts of the 132 kV and 66 kV network to be represented.

The object of the studies is, however, to show the impact of the renewable schemes on future system performance, i.e. whether or not they improve conditions. In that respect their

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[12] The renewable schemes could provide NEDL with a positive benefit in that they could delay some of the reinforcement work that would be required before 2009/10 providing their availability can be relied upon.

importance is more with regard to the relative performance of the system with the renewables in service than in obtaining exactly the same power flows and voltages as those presented in the Seven Year Statement.

Base Case Load Flow. Load flow studies of peak demand for 2003/04 show that with all plant in service and all circuits available, the existing North East Grid system is operating within rating except for the 275/132 kV 120 MVA transformers at Stella West which can be subject to a marginal overload under worst case conditions (i.e. an overload of less than 5 percent). However, this potential overloading has been recognised by NGC and the process to reinforce the 120 MVA units with 240 MVA units is underway.

Elsewhere across the North East Grid utilisation levels on 400 kV, 275 kV and 132 kV circuits are maintained below 50% in most cases. Voltage levels are maintained within +/-5 percent of nominal across the network.

Outages. Contingency analysis of single circuit outages across the network has identified potential overloading problems in three areas:

a) The supply from Stella West to Stella South, which supplies Annfield and Coalburns, is under-capacity as identified above and this has the potential to overload the network in this area and depress the voltage on the 132 kV and 66 kV networks.

b) An outage of one of the two Norton - North Tees 132 kV feeders will marginally overload the second feeder (by approximately 6%) at peak load.

c) An outage of one of the incoming 132 kV feeders at Linton will overload the surviving feeder and transformer.

Notwithstanding the current problems with insufficient 275/132 kV transformer capacity at Stella West, examination of double circuit outages on the 400 kV and 275 kV system showed the system performed satisfactorily with respect to circuit and equipment thermal ratings and voltage limits.

Short-circuit fault levels. The study of maximum 3-phase fault levels in 2003/04 shows good correlation with that presented by NGC in its 2003 Seven Year Statement and confirms that the system short circuit levels are within the associated switchgear rating.

5.4 2009/10 system performance with no renewable generation

Base Case Load Flow. Load flow studies of the 2009/10 system peak demand with no additional renewable energy schemes in service still show the Stella West 275/132 kV transformers to be marginally overloaded despite their reinforcement with an additional 240 MVA transformer. Elsewhere circuit loadings are all within rating and voltage levels are satisfactory. However, utilisation levels have increased from 2003/04 levels. This is particularly significant for Blyth (up to 67%), Lackenby (over 70%), Norton (almost 60%), Annfield (over 70%) and Spadeadam (about 70%). Utilisation levels of this order are indicative of possible overloading and voltage problems under outage conditions (see below).

Outages. Contingency studies of single circuit outages have identified overloads and low voltages associated with a number of outage conditions. These are summarised below:

a) Overloads (up to 20%) and low voltages on the Stella South – Annfield - Coalburns circuits under local outage conditions.

b) Major overloads on the Blyth transformers (over 50%) and low voltage problems in the Blyth to Linton area in the event of a local outage.

c) Overload problems on the Norton – North Tees circuits (over 25%) under outage conditions.

d) Overloads on the Spennymoor and Toronto transformers (below 10%) under outage conditions.

e) Overloads on the Hartmoor transformers (below 10%) under outage conditions.

f) Overloads on the Lackenby 275/66 kV transformers (below 10%) under outage conditions.

These outages are mainly associated with the NGC-NEDL network interface or the NEDL network itself for which no comparable NGC or NEDL results were available. Discussions with NEDL planning engineers are scheduled to discuss the validity of the results.

The double circuit outage studies that are concentrated on the 400 kV and 275 kV network again show the system to operate satisfactorily and remain intact with no overloads or voltage problems identified except those associated with the Stella West 275/132 kV transformers (identified as overloaded even in studies of the base case).

Short-circuit fault levels. The maximum 3-phase short circuit levels determined in the study again show good correlation with those presented in NGC's Seven Year Statement. The fault levels at the main busbars are all within the switchgear rating except those associated with the Norton 275 kV busbar. Here the 3-phase r.m.s. symmetrical break duty is 33.2 kA, compared with the NGC' estimate of 35.2 kA and the switchgear rating of 31.5 kA. In practice, to maintain the fault level below the switchgear rating we would expect the 275 kV bus to be split.

It should be remembered that this study has considered only load flow and short circuit issues. Potential voltage stability/voltage collapse issues when the network is subjected to faults with asynchronous generation such as wind. With the advent of Double Fed Induction Generators (DFIG) or equivalent alternatives these issues can be managed, but will need to be considered in detail on a project-by-project basis. Similarly voltage variation with fluctuating levels of wind power needs to be considered, but can also be managed.

5.5 2009/10 system performance with renewable generation

Base Case Load Flow. Load flow studies were undertaken for the three renewable generation cases presented in Table 5.1:

- Minimum renewable generation (373 MW)
- Moderate renewable generation (888 MW)
- Maximum renewable generation (1666 MW)

Table 5.2 shows the circuit loadings for each of the three cases under base case conditions, i.e. 2009/10 peak demand with all circuits and conventional plant available. The table also shows the results of the two comparable studies for 2003/04 and 2009/10 with no renewable generation in service. Circuit ratings are included in the table.

As in the previous cases (described in sections 5.3 and 5.4), apart from the overloading on the Stella West transformers, the rest of the network is operated within rating.

As the level of renewable generation increases, depending on where it is situated on the network, the circuit loading will change.

Table 5.3 shows the utilisation levels[13] on each circuit represented in the model for the 2003/04 and 2009/10 base case conditions (with no renewable generation installed) and the 2009/10 case with maximum renewable generation. A summary is given below of the principal changes in percentage utilisation as a result of the operation of renewable generation on the system.

Increased utilisation is experienced on:

a) The Spadeadam – Kielder 33 kV circuit and 33/11 kV transformers at each end of the line (from 10% to 60%) which will require either upgrading to enable the hydro and renewables schemes to export their full capacity, or a reduction in the assumed size of these schemes.

b) All 400 kV circuits from Hawthorn Pit, through Norton, Seal Sands and Lackenby and south over the Yorkshire lines (basically doubling utilisation levels to about 40% on most circuits) as the power exported from the region increases as a result of the added renewables and the power imported from Norway.

Reduced utilisation, on the other hand, is experienced on:

a) The Spadeadam 132/11 kV transformers as the supply changes from an importer of power to an exporter as a result of the two smaller renewable schemes at Kielder which generate an aggregated maximum power of 13 MW.

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[13] The percentage utilisation of a circuit is a measure of the loading on a circuit as a percentage of its rating. Utilisation levels of 50% or above can be indicative of a potential overload under single circuit outage conditions depending on the number of parallel circuits.

b) The Blyth 275/132 kV and 275/66 kV transformers, where utilisation falls by about 20% on each transformer (i.e. from between 55 and 65% to between 35 and 45%).

c) Durham Coast 275 kV circuits where again (with a couple of exceptions) utilisations falls by about 20% as a result of the significant quantities of renewable generation planned for the coastal strip and also offshore.

d) Lackenby 275/66 kV transformers, with utilisation levels down from 73% to 43%, due largely to the embedded renewable generation in that area.

e) The 275/132 kV transformers at Norton and 275/66 kV transformers at Hartmoor and Hawthorn Pit, where the embedded renewable generation in these areas effectively reduces the load and therefore reduces the utilisation, particularly on the 275/66 kV transformers where reductions of 30 to 40% are possible.

The impact on circuit utilisation is generally greatest with the maximum renewable case and this is clearly demonstrated in our study of outage conditions.

The studies confirm the feasibility of connecting a 500 MW wind-farm located in the Kielder area into the 275 kV circuits that run between Stella West and Blyth on the east coast and Harker on the west coast. The studies have been based on connection into an upgraded Fourstones grid station, but an alternative based on a new substation closer to Harker or a connection to Harker itself may be preferred.

Table 5.2: Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

🟩 branch removed
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Grid area	Send bus	Bus No	Rec bus	Bus No.	Circuit type	Circuit No.	Voltage (kV)	Length (km)	Rating (MVA)	2003/04	2009/10				Comments
										No renewables	No renewables	Minimum renewables	Moderate renewables	Maximum renewables	
Stella - Border	**STWB40**	405	**STEW4A**	403	1	1	400	94.9	1110	568	575	573	572	571	
	STWB40	406	**STEW4B**	404	1	1	400	94.9	1100	583	591	588	587	586	
	STEW4A	403	**STEW21**	202	2	1	400/275	-	1000	207	260	259	259	259	
	STEW4A	403	**STEW21**	202	2	2	400/275	-	1000	305	309	259	307	307	
	STEW4B	404	**STEW22**	207	2	1	400/275	-	1000	288	291	290	290	289	
	STEW4B	404	**STEW22**	207	2	2	400/275	-	1000	289	292	291	291	290	
	STEW21	202	**STEW22**	207	5	-	275	-	-	185	36	71	37	91	
	STEW21	202	**STEN11**	100	2	1	275/132	-	120	125	122	122	122	122	275/132 kV 120 MVA transformers are being replaced by 240 MVA units
	STEW21	202	**STEN11**	100	2	2	275/132	-	120	125	122	122	122	122	275/132 kV 120 MVA transformers are being replaced by 240 MVA units
	STEW22	207	**STEN12**	110	2	1	275/132	-	120	125	122	122	122	122	275/132 kV 120 MVA transformers are being replaced by 240 MVA units
	STEW21	202	**STES11**	101	2	1	275/132	-	120	125	122	122	122	122	275/132 kV 120 MVA transformers are being replaced by 240 MVA units
	STEW22	207	**STES12**	124	2	1	275/132	-	120	125	122	122	122	122	275/132 kV 120 MVA transformers are being replaced by 240 MVA units
	STEW22	207	**STES12**	124	2	2	275/132	-	240	-	184	184	183	183	
	STEN11	100	**STES12**	124	4	1	132	0.7	274	92	10	10	10	10	
	STES11	101	**STES12**	124	5	-	132	-	-	46	88	88	88	88	
Blyth - Harker	**BLYT21**	200	**STEW21**	202	1	1	275	27.4	550	97	145	106	110	112	
	BLYT21	200	**STEW21**	202	4	2	275	34.7	525	97	147	107	111	113	
	BLYT22	201	**STEW22**	207	1	1	275	27.4	550	122	147	134	179	212	
	BLYT21	201	**FOUR20**	220	4	1	275	47.8	700	50	176	🟩	🟩	🟩	Fourstones 275 kV bus split by 2009/10
	FOUR20	220	**HARK22**	224	4	1	275	60.1	700	37	158	🟩	🟩	🟩	Fourstones 275 kV bus split by 2009/10
	STEW22	207	**HARK21**	223	4	1	275	84.0	675	72	204	🟩	🟩	🟩	OHL routed through Fourstones by 2009/10
	BLYT21	200	**FOUR22**	251	4	1	275	47.8	700	-	-	73	92	176	Fourstones 275 kV grid station up-graded & bus numbering changed
	FOUR22	251	**HARK21**	223	4	1	275	60.1	700	-	-	146	137	130	Fourstones 275 kV grid station up-graded & bus numbering changed
	STEW22	207	**FOUR21**	202	4	1	275	23.9	675	-	-	253	127	209	Fourstones 275 kV grid station up-graded & bus numbering changed
	FOUR21	202	**HARK22**	224	4	1	275	60.1	675	-	-	87	100	55	Fourstones 275 kV grid station up-graded & bus numbering changed
	FOUR21	250	**FOUR22**	251	5	-	275	-	-	-	-	87	100	55	Fourstones 275 kV grid station up-graded & bus numbering changed
	FOUR21	250	**FOUR10**	3100	2	1	275/132	-	180	-	-	50	99	149	Fourstones 275 kV grid station up-graded & bus numbering changed
	FOUR10	3100	**HEAL10**	3104	1	1	132	15.6	116	-	-	50	50	50	To be connected to Coalburns instead
	FOUR10	3100	**COLT10**	3101	1	1	132	7.8	116	-	-	-	50	100	Supply to new renewables
	COLT10	3101	**COWD10**	3102	1	1	132	5.0	116	-	-	-	50	50	Supply to new renewables
	FOUR22	251	**WAIN2B**	2202	1	1	275	38.2	550	-	-	-	250	250	Supply to new renewables
	FOUR21	250	**WAIN2A**	2201	1	1	275	38.2	550	-	-	-	-	250	Supply to new renewables
Harker - Kielder	**HARK21**	223	**HARK40**	407	2	1	400/275	-	500	50	127	106	106	106	
	HARK21	223	**HARK40**	407	2	2	400/275	-	500	52	127	106	106	110	
	HARK22	224	**HARK40**	407	2	1	400/275	-	500	58	41	46	42	39	
	HARK22	224	**HARK40**	407	2	2	400/275	-	500	58	41	45	42	38	
	HARK21	223	**HARK22**	224	5	-	275	-	-	-	-	-	-	-	
	HARK21	223	**HARK11**	121	2	1	275/132	-	120	62	76	70	69	69	
	HARK21	223	**HARK11**	121	2	2	275/132	-	120	62	76	70	69	69	
	HARK22	224	**HARK12**	122	2	1	275/132	-	120	42	50	51	51	51	
	HARK22	224	**HARK12**	122	2	2	275/132	-	120	42	50	51	51	51	
	HARK22	224	**HARK12**	122	2	3	275/132	-	120	42	50	51	51	51	
	HARK11	121	**HARK12**	122	5	-	132	-	-	9	5	10	10	11	
	HARK11	121	**SPAD1A**	133	1	1	132	26.1	87	8	9	6	6	6	
	HARK12	122	**SPAD1B**	134	1	1	132	26.1	87	8	9	6	6	6	
	SPAD1A	133	**SPAD50**	2000	2	1	132/11	-	30	15	17	5	5	5	
	SPAD1B	134	**SPAD50**	2000	2	1	132/11	-	30	15	17	5	5	5	
	SPAD50	2000	**SPAD30**	2301	2	1	132/11	-	18	2	2	11	11	11	7.5 MVA tx replaced by 18 MVA unit
	SPAD30	2301	**KIEL30**	2302	1	1	33	29.1	20	2	2	11	11	11	
	KIEL30	2302	**KIEL50**	2001	2	1	33/11	-	18	-	-	11	11	11	7.5 MVA tx replaced by 18 MVA unit

Table 5.2 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

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🟨 new branch

Grid area	Send bus	Bus No	Rec bus	Bus No.	Circuit type	Circuit No.	Voltage (kV)	Length (km)	Rating (MVA)	2003/04 No renewables	2009/10 No renewables	2009/10 Minimum renewables	2009/10 Moderate renewables	2009/10 Maximum renewables	Comments
Durham coast	**BLYT21**	200	**BLYT1A**	108	2	1	275/132	-	240	49	161	131	134	112	
	BLYT2A	226	**BLYT1B**	109	2	1	275/132	-	240	54	158	125	123	100	
	BLYT21	200	**BLYT61**	614	2	1	275/66	-	120	60	70	65	65	50	
	BLYT22	201	**BLYT62**	615	2	1	275/66	-	120	57	69	61	59	42	
	BLYT2A	226	**BLYT62**	615	2	1	275/66	-	180	86	103	92	88	63	
	BLYT21	200	**BLYT2A**	226	5	-	275	-	-	33	260	216	209	157	
	BLYT21	200	**TYNE20**	206	1	1	275	16.7	1070	153	73	43	124	257	
	TYNE20	206	**WBOL20**	208	1	1	275	11.5	920	83	330	262	172	107	
	BLYT22	201	**SSHI20**	205	1	1	275	23.7	1070	59	188	153	117	95	
	SSHI20	205	**WBOL20**	208	1	1	275	4.4	920	55	238	201	158	99	
	WBOL20	208	**OFFE20**	211	1	1	275	8.3	920	99	454	407	336	230	
	OFFE20	211	**HAWP21**	212	1	1	275	9.5	920	161	532	484	413	306	
	HAWP22	227	**HARM20**	213	1	1	275	17.3	920	260	347	310	280	248	
	HARM20	213	**HATL20**	214	1	1	275	14.0	920	363	476	426	353	263	
	WBOL20	208	**HATL20**	214	1	1	275	49.3	920	242	🟩	🟩	🟩	🟩	Routed via Hawthorn Pit by 2009/10
	HATL20	214	**SALH20**	215	1	1	275	8.7	1200	509	714	698	661	641	
	HATL20	214	**TODP20**	216	1	1	275	17.0	1200	64	53	77	143	207	
	TODP20	216	**LACK22**	225	1	1	275	6.0	920	319	452	420	349	285	
	SALH20	215	**NORT22**	210	1	1	275	12.4	1200	380	557	541	506	486	
Teesside	**LACK40**	401	**NORT40**	400	4	1	400	21.6	1320	415	🟩	🟩	🟩	🟩	Circuit routed through Seal Sands after 2006/07
	LACK40	401	**SEAS40**	414	4	1	400	6.9	1320	-	🟨 251	306	421	594	Seal Sands power station connected into Lackenby-Norton 400 kV circuit
	SEAS40	414	**NORT40**	400	1	1	400	14.8	2960	-	🟨 584	491	345	164	Seal Sands power station connected into Lackenby-Norton 400 kV circuit
	LACK21	217	**LACK40**	401	2	1	400/275	-	1000	200	32	91	173	314	
	LACK2A	218	**LACK40**	401	2	1	400/275	-	1000	371	368	368	368	368	
	LACK2B	219	**LACK40**	401	2	1	400/275	-	1000	371	369	369	369	368	
	LACK21	217	**LACK22**	225	5	-	275	-	-	49	172	130	61	54	
	LACK2A	218	**GRST21**	221	4	1	275	1.2	1000	369	368	368	368	367	
	LACK2B	219	**GRST21**	221	4	1	275	1.2	1000	369	368	368	368	368	
	LACK21	217	**GRST22**	222	4	1	275	0.9	1000	368	368	369	369	371	
	LACK22	225	**GRST22**	222	4	1	275	0.9	1000	368	368	369	369	371	
	LACK21	217	**LACK61**	612	2	1	275/66	-	120	75	87	77	74	51	
	LACK21	217	**LACK61**	612	2	2	275/66	-	120	75	87	77	74	51	
	LACK22	225	**LACK62**	613	2	1	275/66	-	120	75	87	77	74	51	
	LACK61	612	**LACK62**	613	5	-	66	-	-	46	52	58	60	43	
Yorkshire lines	**LACK40**	401	**THTO41**	413	4	1	400	100.5	2210	311	463	537	649	814	
	LACK40	401	**THTO42**	413	4	1	400	100.5	2210	311	463	537	649	814	
	NORT40	400	**OSBA40**	411	1	1	400	84.1	1750	186	345	434	570	765	
	NORT40	400	**THTO42**	413	1	1	400	101.0	1750	156	🟩	🟩	🟩	🟩	Circuit routed via Osbaldwick by 2009/10
	NORT40	400	**OSBA40**	411	1	2	400	84.1	1750	-	🟨 345	434	570	765	
	OSBA40	411	**THTO41**	412	1	1	400	16.9	2220	55	208	297	434	630	
	OSBA40	411	**THTO41**	412	1	2	400	16.9	2220	-	🟨 208	297	434	630	
	THTO41	412	**THTO42**	413	5	-	400	-	-	-	454	526	649	798	

Table 5.2 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

🟩 branch removed
🟧 new branch

										2003/04	2009/10				
Grid area	**Send bus**	**Bus No**	**Rec bus**	**Bus No.**	**Circuit type**	**Circuit No.**	**Voltage (kV)**	**Length (km)**	**Rating (MVA)**	**No renewables**	**No renewables**	**Minimum renewables**	**Moderate renewables**	**Maximum renewables**	**Comments**
Norton - Hawthorn Pit	**NORT21**	209	**NORT40**	400	2	1	400/275	-	1000	176	273	212	124	111	
	NORT22	210	**NORT40**	400	2	1	400/275	-	1000	83	287	222	131	117	
	NORT21	209	**NORT11**	119	2	1	275/132	-	240	95	140	140	125	125	
	NORT21	209	**NORT11**	119	2	2	275/132	-	240	95	140	140	125	125	
	NORT22	210	**NORT12**	120	2	1	275/132	-	240	132	140	140	125	125	
	NORT22	210	**NORT12**	120	2	2	275/132	-	240	132	140	140	125	125	
	NORT21	209	**NORT22**	210	5	-	275	-	-	-	320	312	285	266	
	NORT11	119	**NORT12**	120	5	-	132	-	-	38	28	28	40	40	
	NORT40	400	**HAWP4A**	402	1	1	400	27.5	2220	52	🟩	🟩	🟩	🟩	Hawthorn Pit 400 kV bus established, major re-configuration
	HAWP22	227	**HAWP4A**	402	2	1	400/275	-	1000	52	🟩	🟩	🟩	🟩	Hawthorn Pit 400 kV bus established, major re-configuration
	HAWP21	212	**NORT22**	210	4	1	275	28.1	720	34	🟩	🟩	🟩	🟩	Hawthorn Pit 400 kV bus established, major re-configuration
	NORT40	400	**HAWP40**	402	1	1	400	27.5	2220	-	306	376	480	630	Associated with new bus numbering & new 400 kV line
	NORT40	400	**HAWP40**	402	2	2	400	27.6	2220	-	307	378	482	633	Associated with new bus numbering & new 400 kV line
	HAWP40	402	**HAWP22**	227	2	1	400/275	-	1000	-	343	274	185	84	Associated with new bus numbering & new 400 kV line
	HAWP40	402	**HAWP2A**	228	2	1	400/275	-	1100	-	17	4	35	83	Associated with new bus numbering & new 400 kV line
	HAWP2B	229	**HAWP40**	402	2	1	400/275	-	1100	-	393	330	242	135	Associated with new bus numbering & new 400 kV line
	HAWP2A	228	**HATL20**	214	1	1	275	31.4	920	-	18	4	35	83	Associated with new bus numbering & new 400 kV line
	HAWP21	212	**HAWP61**	608	2	1	275/66	-	180	61	76	47	24	13	
	HAWP22	227	**HAWP62**	609	2	1	275/66	-	180	61	76	47	24	13	
	HAWP21	212	**HAWP22**	227	5	-	275	-	-	189	607	531	436	307	
	HARM20	213	**HARM61**	610	2	1	275/66	-	120	52	63	57	36	13	
	HARM20	213	**HARM62**	611	2	1	275/66	-	120	61	63	57	36	13	
	WBOL20	208	**HAWP2B**	229	1	1	275	17.8	920	-	386	324	242	133	Associated with Hawthorn Pit re-configuration
Stella - Annfield	**STES11**	101	**COAL1A**	102	1	1	132	9.1	112	34	41	41	41	41	
	COAL1A	102	**COAL60**	600	2	1	132/66	-	90	34	40	41	41	41	
	STES11	101	**ANNF1A**	104	1	1	132	16.9	112	33	43	43	43	43	
	ANNF1A	132	**ANNF60**	601	2	1	132/66	-	90	33	42	42	42	42	
	STES12	124	**ANNT10**	106	1	1	132	4.8	112	67	82	82	82	82	
	ANNT10	106	**COAL1B**	103	1	1	132	4.4	112	34	40	40	40	40	
	COAL1B	103	**COAL60**	600	2	1	132/66	-	90	34	40	40	40	40	
	ANNT10	106	**ANNF1B**	105	1	1	132	11.8	112	33	42	42	42	42	
	ANNF1B	105	**ANNF60**	601	2	1	132/66	-	90	33	42	42	42	42	

Table 5.2 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

🟩 branch removed
🟨 new branch

Grid area	Send bus	Bus No	Rec bus	Bus No.	Circuit type	Circuit No.	Voltage (kV)	Length (km)	Rating (MVA)	2003/04 No renewables	2009/10 No renewables	2009/10 Minimum renewables	2009/10 Moderate renewables	2009/10 Maximum renewables	Comments
Stella - Spennymoor	**STEW21**	202	**SPEN21**	203	4	1	275	39.2	955	208	68				Branch split for Tee-off
	STEW22	207	**SPEN22**	204	1	1	275	39.1	1020	76	109				Branch split for Tee-off
	STEW21	202	**GRPF2A**	240	4	1	275	25.0	955	-	-	44	44	108	Branch split following Tee-off
	GRPF2A	240	**SPEN21**	203	4	1	275	14.2	955	-	-	41	73	198	Branch split following Tee-off
	STEW22	207	**GRPF2B**	241	1	1	275	15.0	1020	-	-	110	56	96	Branch split following Tee-off
	GRPF2B	241	**SPEN22**	204	1	1	275	24.2	1020	-	-	57	53	177	Branch split following Tee-off
	GRPF2A	240	**SC2820**	4203	1	1	275	5.1	181	-	-	-	51	101	*Assumed 380A rated OHL (as per Harker - Spadeadam 132 kV line)
	SC2820	4203	**SC2850**	4103	2	1	275/11	-	63	-	-	-	50	50	
	SC2820	4203	**SC2920**	4204	1	1	275	3.6	181	-	-	-	-	50	*Assumed 380A rated OHL (as per Harker - Spadeadam 132 kV line)
	SC2920	4204	**SC2950**	4104	2	1	275/11	-	63	-	-	-	-	50	
	GRPF2B	241	**SC1420**	4201	1	1	275	4.5	181	-	-	51	51	101	*Assumed 380A rated OHL (as per Harker - Spadeadam 132 kV line)
	SC1420	4201	**SC1450**	4101	2	1	275/11	-	63	-	-	51	50	50	
	SC1420	4201	**SC1520**	4202	1	1	275	3.0	181	-	-	-	-	50	*Assumed 380A rated OHL (as per Harker - Spadeadam 132 kV line)
	SC1520	4202	**SC1550**	4102	2	1	275/11	-	63	-	-	-	-	50	
	SPEN21	203	**NORT21**	209	1	1	275	21.1	875	83	309	240	157	119	
	SPEN22	204	**NORT22**	210	1	1	275	21.0	875	78	236	166	102	127	
	SPEN21	203	**SPEN11**	117	2	1	275/132	-	240	88	122	101	101	86	
	SPEN21	203	**SPEN11**	117	2	2	275/132	-	240	88	122	101	101	86	
	SPEN22	204	**SPEN12**	118	2	1	275/132	-	240	115	130	109	108	91	
	SPEN21	203	**SPEN22**	204	5	-	275	-	-	-	-	-	-	-	
	SPEN11	117	**SPEN61**	604	2	1	132/66	-	75	40	52	52	52	52	
	SPEN11	117	**SPEN61**	604	2	2	132/66	-	75	41	53	53	53	53	
	SPEN12	118	**SPEN62**	605	2	2	132/66	-	75	40	52	52	52	52	
	SPEN11	117	**TORO60**	606	2	1	132/66	-	90	38	46	18	18	17	
	SPEN12	118	**TORO60**	606	2	1	132/66	-	90	38	46	18	18	17	
	SPEN61	604	**SPEN62**	605	5	-	66	-	-	20	26	26	26	13	
	TORO60	606	**SC1860**	5600	1	1	66	8.2	57	-	-	50	50	49	Supply to new renewables
	SC1860	5600	**SC1870**	5001	2	1	66/22	-	63	-	-	51	51	50	Supply to new renewables
	TORO60	606	**FLYT61**	5601	1	1	66	3.7	57	N/A	N/A	23	23	6	
	FLYT61	5601	**FLYB60**	5603	1	1	66	3.3	57	N/A	N/A	12	12	6	
	TORO60	606	**FLYT62**	5602	1	1	66	3.7	57	N/A	N/A	23	23	12	
	FLYT62	5602	**FLYB60**	5603	1	1	66	3.4	57	N/A	N/A	12	12	12	
	FLYT61	5601	**HARB61**	5604	1	1	66	18.6	38	N/A	N/A	11	11	11	
	FLYT62	5602	**HARB62**	5605	1	1	66	18.7	38	N/A	N/A	11	11	11	
	HARB61	5604	**HARB62**	5605	5	-	66	-	-	N/A	N/A	0	0	25	
	HARB61	5604	**SC2360**	5606	1	1	66	5.7	57	-	-	-	-	50	Supply to new renewables
	SC2360	5606	**SC2370**	5003	2	2	66/22	-	63	-	-	-	-	50	Supply to new renewables

Key to circuit types
1=ohl
2=tx
3=cable
4=composite cct (ohl + cable)
5=bus section switch

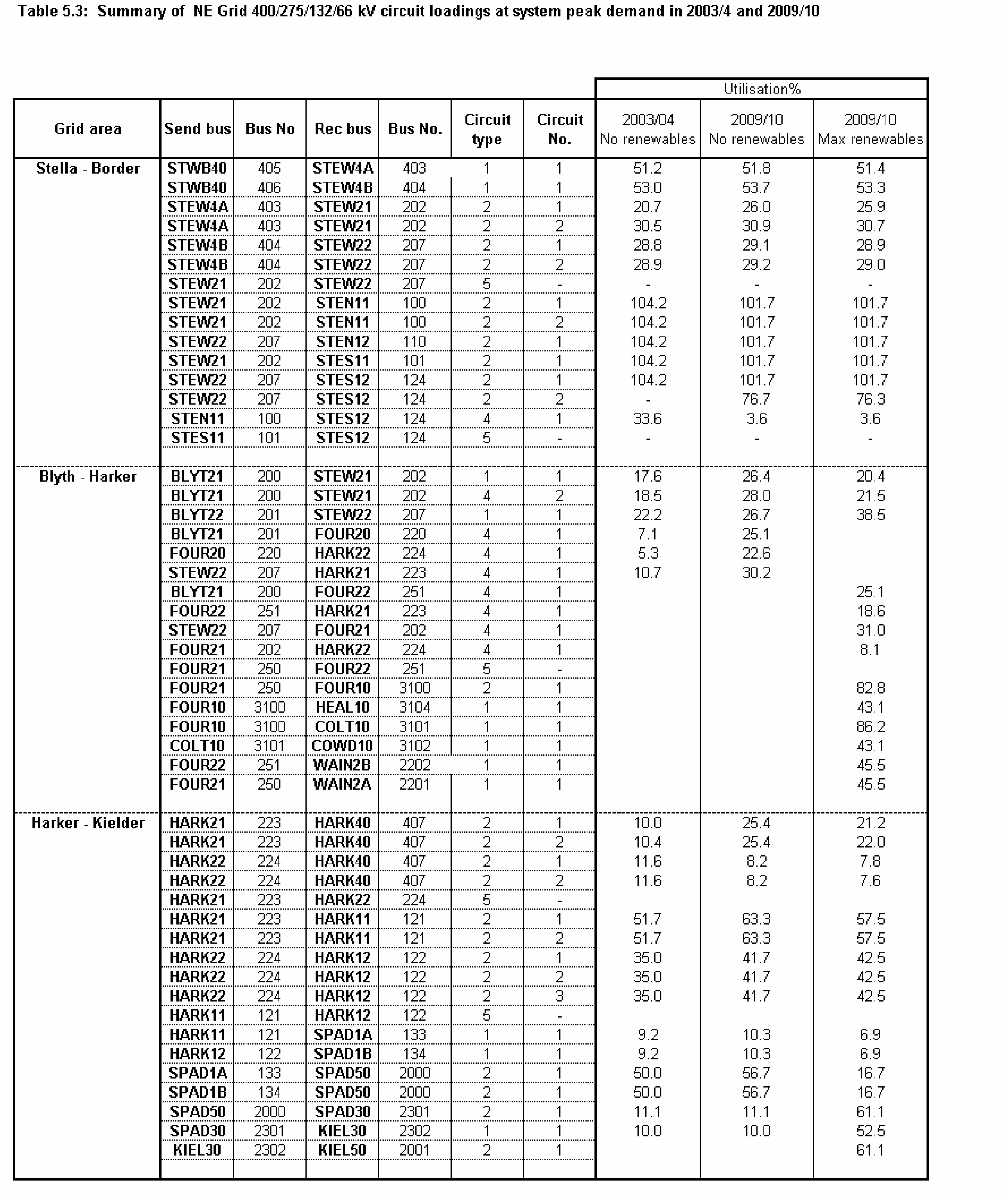

Table 5.3: Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

							Utilisation%		
Grid area	Send bus	Bus No	Rec bus	Bus No.	Circuit type	Circuit No.	2003/04 No renewables	2009/10 No renewables	2009/10 Max renewables
Stella - Border	STWB40	405	STEW4A	403	1	1	51.2	51.8	51.4
	STWB40	406	STEW4B	404	1	1	53.0	53.7	53.3
	STEW4A	403	STEW21	202	2	1	20.7	26.0	25.9
	STEW4A	403	STEW21	202	2	2	30.5	30.9	30.7
	STEW4B	404	STEW22	207	2	1	28.8	29.1	28.9
	STEW4B	404	STEW22	207	2	2	28.9	29.2	29.0
	STEW21	202	STEW22	207	5	-	-	-	-
	STEW21	202	STEN11	100	2	1	104.2	101.7	101.7
	STEW21	202	STEN11	100	2	2	104.2	101.7	101.7
	STEW22	207	STEN12	110	2	1	104.2	101.7	101.7
	STEW21	202	STES11	101	2	1	104.2	101.7	101.7
	STEW22	207	STES12	124	2	1	104.2	101.7	101.7
	STEW22	207	STES12	124	2	2	-	76.7	76.3
	STEN11	100	STES12	124	4	1	33.6	3.6	3.6
	STES11	101	STES12	124	5	-	-	-	-
Blyth - Harker	BLYT21	200	STEW21	202	1	1	17.6	26.4	20.4
	BLYT21	200	STEW21	202	4	2	18.5	28.0	21.5
	BLYT22	201	STEW22	207	1	1	22.2	26.7	38.5
	BLYT21	201	FOUR20	220	4	1	7.1	25.1	
	FOUR20	220	HARK22	224	4	1	5.3	22.6	
	STEW22	207	HARK21	223	4	1	10.7	30.2	
	BLYT21	200	FOUR22	251	4	1			25.1
	FOUR22	251	HARK21	223	4	1			18.6
	STEW22	207	FOUR21	202	4	1			31.0
	FOUR21	202	HARK22	224	4	1			8.1
	FOUR21	250	FOUR22	251	5	-			
	FOUR21	250	FOUR10	3100	2	1			82.8
	FOUR10	3100	HEAL10	3104	1	1			43.1
	FOUR10	3100	COLT10	3101	1	1			86.2
	COLT10	3101	COWD10	3102	1	1			43.1
	FOUR22	251	WAIN2B	2202	1	1			45.5
	FOUR21	250	WAIN2A	2201	1	1			45.5
Harker - Kielder	HARK21	223	HARK40	407	2	1	10.0	25.4	21.2
	HARK21	223	HARK40	407	2	2	10.4	25.4	22.0
	HARK22	224	HARK40	407	2	1	11.6	8.2	7.8
	HARK22	224	HARK40	407	2	2	11.6	8.2	7.6
	HARK21	223	HARK22	224	5	-			
	HARK21	223	HARK11	121	2	1	51.7	63.3	57.5
	HARK21	223	HARK11	121	2	2	51.7	63.3	57.5
	HARK22	224	HARK12	122	2	1	35.0	41.7	42.5
	HARK22	224	HARK12	122	2	2	35.0	41.7	42.5
	HARK22	224	HARK12	122	2	3	35.0	41.7	42.5
	HARK11	121	HARK12	122	5	-			
	HARK11	121	SPAD1A	133	1	1	9.2	10.3	6.9
	HARK12	122	SPAD1B	134	1	1	9.2	10.3	6.9
	SPAD1A	133	SPAD50	2000	2	1	50.0	56.7	16.7
	SPAD1B	134	SPAD50	2000	2	1	50.0	56.7	16.7
	SPAD50	2000	SPAD30	2301	2	1	11.1	11.1	61.1
	SPAD30	2301	KIEL30	2302	1	1	10.0	10.0	52.5
	KIEL30	2302	KIEL50	2001	2	1			61.1

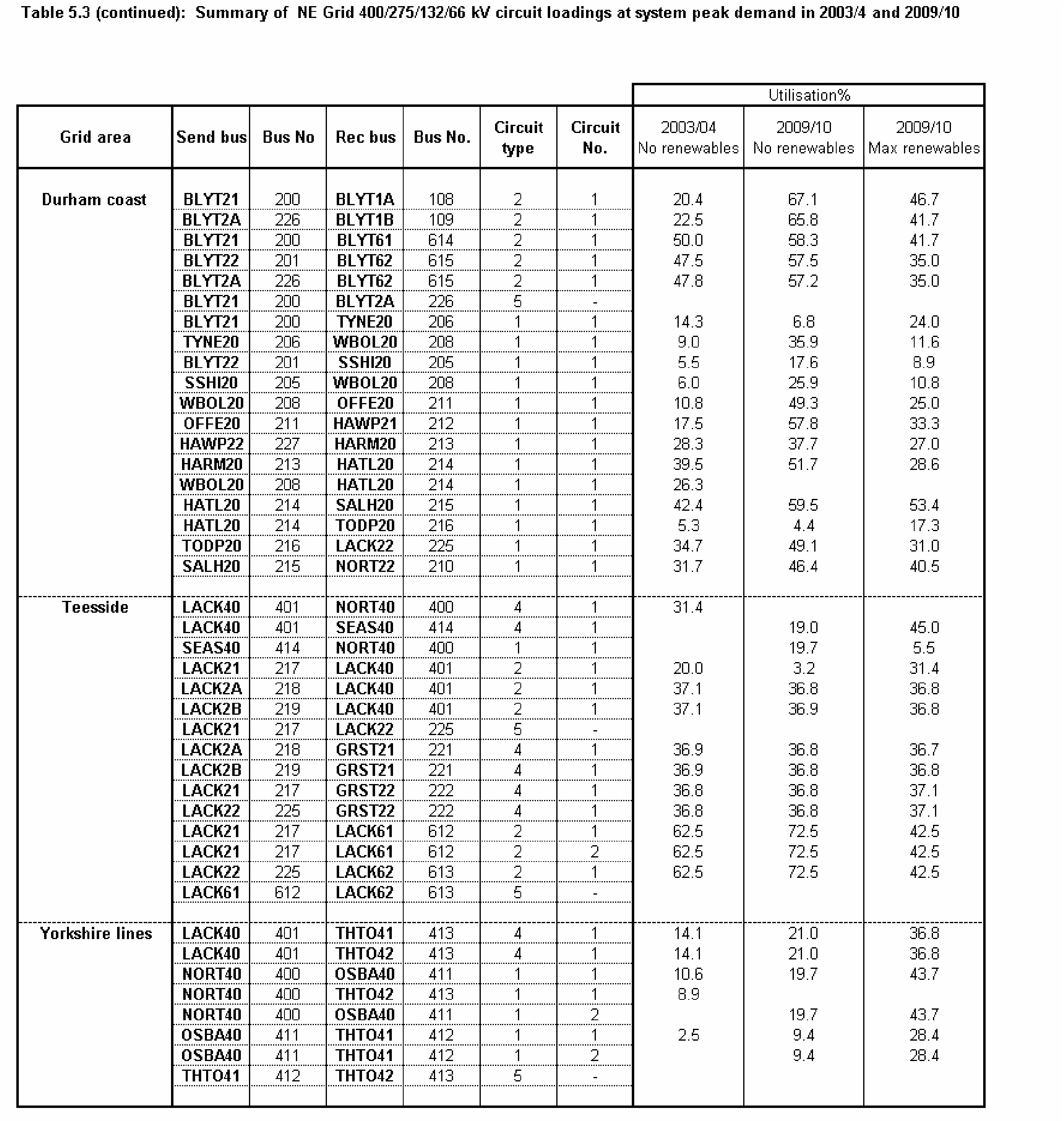

Table 5.3 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

Grid area	Send bus	Bus No	Rec bus	Bus No.	Circuit type	Circuit No.	Utilisation%		
							2003/04 No renewables	2009/10 No renewables	2009/10 Max renewables
Durham coast	BLYT21	200	BLYT1A	108	2	1	20.4	67.1	46.7
	BLYT2A	226	BLYT1B	109	2	1	22.5	65.8	41.7
	BLYT21	200	BLYT61	614	2	1	50.0	58.3	41.7
	BLYT22	201	BLYT62	615	2	1	47.5	57.5	35.0
	BLYT2A	226	BLYT62	615	2	1	47.8	57.2	35.0
	BLYT21	200	BLYT2A	226	5	-			
	BLYT21	200	TYNE20	206	1	1	14.3	6.8	24.0
	TYNE20	206	WBOL20	208	1	1	9.0	35.9	11.6
	BLYT22	201	SSHI20	205	1	1	5.5	17.6	8.9
	SSHI20	205	WBOL20	208	1	1	6.0	25.9	10.8
	WBOL20	208	OFFE20	211	1	1	10.8	49.3	25.0
	OFFE20	211	HAWP21	212	1	1	17.5	57.8	33.3
	HAWP22	227	HARM20	213	1	1	28.3	37.7	27.0
	HARM20	213	HATL20	214	1	1	39.5	51.7	28.6
	WBOL20	208	HATL20	214	1	1	26.3		
	HATL20	214	SALH20	215	1	1	42.4	59.5	53.4
	HATL20	214	TODP20	216	1	1	5.3	4.4	17.3
	TODP20	216	LACK22	225	1	1	34.7	49.1	31.0
	SALH20	215	NORT22	210	1	1	31.7	46.4	40.5
Teesside	LACK40	401	NORT40	400	4	1	31.4		
	LACK40	401	SEAS40	414	4	1		19.0	45.0
	SEAS40	414	NORT40	400	1	1		19.7	5.5
	LACK21	217	LACK40	401	2	1	20.0	3.2	31.4
	LACK2A	218	LACK40	401	2	1	37.1	36.8	36.8
	LACK2B	219	LACK40	401	2	1	37.1	36.9	36.8
	LACK21	217	LACK22	225	5	-			
	LACK2A	218	GRST21	221	4	1	36.9	36.8	36.7
	LACK2B	219	GRST21	221	4	1	36.9	36.8	36.8
	LACK21	217	GRST22	222	4	1	36.8	36.8	37.1
	LACK22	225	GRST22	222	4	1	36.8	36.8	37.1
	LACK21	217	LACK61	612	2	1	62.5	72.5	42.5
	LACK21	217	LACK61	612	2	2	62.5	72.5	42.5
	LACK22	225	LACK62	613	2	1	62.5	72.5	42.5
	LACK61	612	LACK62	613	5	-			
Yorkshire lines	LACK40	401	THTO41	413	4	1	14.1	21.0	36.8
	LACK40	401	THTO42	413	4	1	14.1	21.0	36.8
	NORT40	400	OSBA40	411	1	1	10.6	19.7	43.7
	NORT40	400	THTO42	413	1	1	8.9		
	NORT40	400	OSBA40	411	1	2		19.7	43.7
	OSBA40	411	THTO41	412	1	1	2.5	9.4	28.4
	OSBA40	411	THTO41	412	1	2		9.4	28.4
	THTO41	412	THTO42	413	5	-			

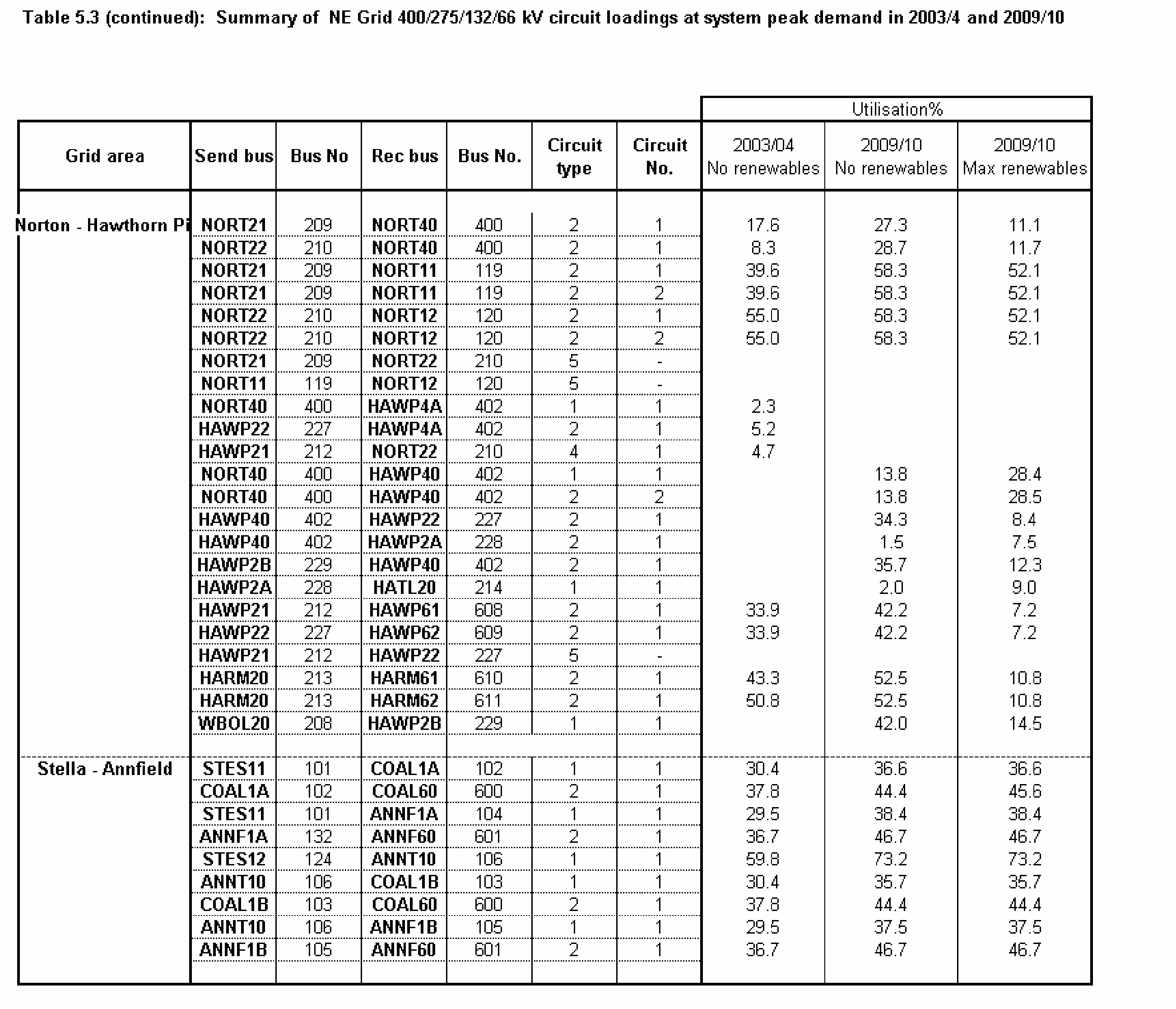

Table 5.3 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

							Utilisation%		
Grid area	**Send bus**	**Bus No**	**Rec bus**	**Bus No.**	**Circuit type**	**Circuit No.**	2003/04 No renewables	2009/10 No renewables	2009/10 Max renewables
Norton - Hawthorn Pi	**NORT21**	209	**NORT40**	400	2	1	17.6	27.3	11.1
	NORT22	210	**NORT40**	400	2	1	8.3	28.7	11.7
	NORT21	209	**NORT11**	119	2	1	39.6	58.3	52.1
	NORT21	209	**NORT11**	119	2	2	39.6	58.3	52.1
	NORT22	210	**NORT12**	120	2	1	55.0	58.3	52.1
	NORT22	210	**NORT12**	120	2	2	55.0	58.3	52.1
	NORT21	209	**NORT22**	210	5	-			
	NORT11	119	**NORT12**	120	5	-			
	NORT40	400	**HAWP4A**	402	1	1	2.3		
	HAWP22	227	**HAWP4A**	402	2	1	5.2		
	HAWP21	212	**NORT22**	210	4	1	4.7		
	NORT40	400	**HAWP40**	402	1	1		13.8	28.4
	NORT40	400	**HAWP40**	402	2	2		13.8	28.5
	HAWP40	402	**HAWP22**	227	2	1		34.3	8.4
	HAWP40	402	**HAWP2A**	228	2	1		1.5	7.5
	HAWP2B	229	**HAWP40**	402	2	1		35.7	12.3
	HAWP2A	228	**HATL20**	214	1	1		2.0	9.0
	HAWP21	212	**HAWP61**	608	2	1	33.9	42.2	7.2
	HAWP22	227	**HAWP62**	609	2	1	33.9	42.2	7.2
	HAWP21	212	**HAWP22**	227	5	-			
	HARM20	213	**HARM61**	610	2	1	43.3	52.5	10.8
	HARM20	213	**HARM62**	611	2	1	50.8	52.5	10.8
	WBOL20	208	**HAWP2B**	229	1	1		42.0	14.5
Stella - Annfield	**STES11**	101	**COAL1A**	102	1	1	30.4	36.6	36.6
	COAL1A	102	**COAL60**	600	2	1	37.8	44.4	45.6
	STES11	101	**ANNF1A**	104	1	1	29.5	38.4	38.4
	ANNF1A	132	**ANNF60**	601	2	1	36.7	46.7	46.7
	STES12	124	**ANNT10**	106	1	1	59.8	73.2	73.2
	ANNT10	106	**COAL1B**	103	1	1	30.4	35.7	35.7
	COAL1B	103	**COAL60**	600	2	1	37.8	44.4	44.4
	ANNT10	106	**ANNF1B**	105	1	1	29.5	37.5	37.5
	ANNF1B	105	**ANNF60**	601	2	1	36.7	46.7	46.7

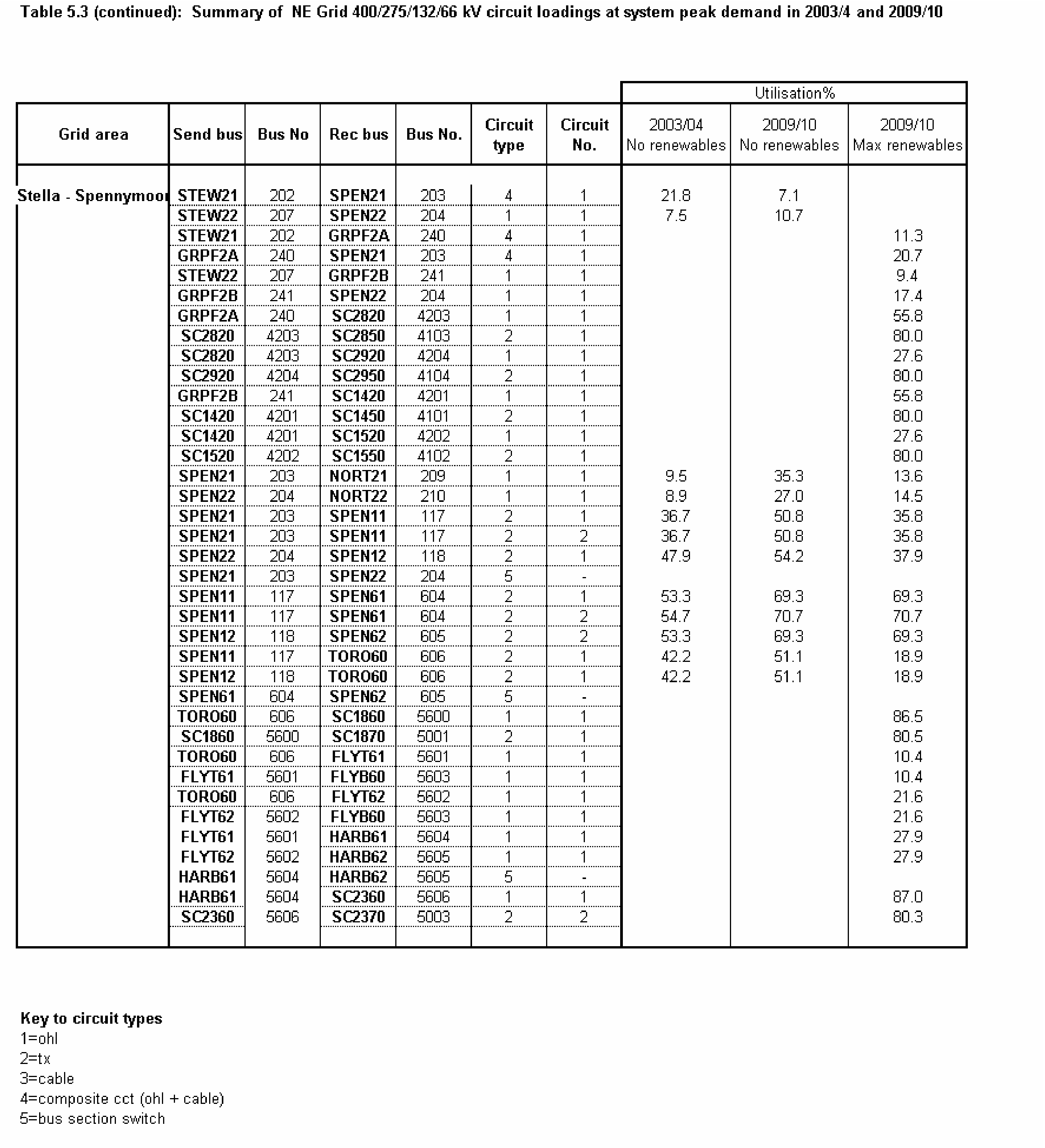

Table 5.3 (continued): Summary of NE Grid 400/275/132/66 kV circuit loadings at system peak demand in 2003/4 and 2009/10

							Utilisation%		
Grid area	**Send bus**	**Bus No**	**Rec bus**	**Bus No.**	**Circuit type**	**Circuit No.**	2003/04 No renewables	2009/10 No renewables	2009/10 Max renewables
Stella - Spennymoor	**STEW21**	202	**SPEN21**	203	4	1	21.8	7.1	
	STEW22	207	**SPEN22**	204	1	1	7.5	10.7	
	STEW21	202	**GRPF2A**	240	4	1			11.3
	GRPF2A	240	**SPEN21**	203	4	1			20.7
	STEW22	207	**GRPF2B**	241	1	1			9.4
	GRPF2B	241	**SPEN22**	204	1	1			17.4
	GRPF2A	240	**SC2820**	4203	1	1			55.8
	SC2820	4203	**SC2850**	4103	2	1			80.0
	SC2820	4203	**SC2920**	4204	1	1			27.6
	SC2920	4204	**SC2950**	4104	2	1			80.0
	GRPF2B	241	**SC1420**	4201	1	1			55.8
	SC1420	4201	**SC1450**	4101	2	1			80.0
	SC1420	4201	**SC1520**	4202	1	1			27.6
	SC1520	4202	**SC1550**	4102	2	1			80.0
	SPEN21	203	**NORT21**	209	1	1	9.5	35.3	13.6
	SPEN22	204	**NORT22**	210	1	1	8.9	27.0	14.5
	SPEN21	203	**SPEN11**	117	2	1	36.7	50.8	35.8
	SPEN21	203	**SPEN11**	117	2	2	36.7	50.8	35.8
	SPEN22	204	**SPEN12**	118	2	1	47.9	54.2	37.9
	SPEN21	203	**SPEN22**	204	5	-			
	SPEN11	117	**SPEN61**	604	2	1	53.3	69.3	69.3
	SPEN11	117	**SPEN61**	604	2	2	54.7	70.7	70.7
	SPEN12	118	**SPEN62**	605	2	2	53.3	69.3	69.3
	SPEN11	117	**TORO60**	606	2	1	42.2	51.1	18.9
	SPEN12	118	**TORO60**	606	2	1	42.2	51.1	18.9
	SPEN61	604	**SPEN62**	605	5	-			
	TORO60	606	**SC1860**	5600	1	1			86.5
	SC1860	5600	**SC1870**	5001	2	1			80.5
	TORO60	606	**FLYT61**	5601	1	1			10.4
	FLYT61	5601	**FLYB60**	5603	1	1			10.4
	TORO60	606	**FLYT62**	5602	1	1			21.6
	FLYT62	5602	**FLYB60**	5603	1	1			21.6
	FLYT61	5601	**HARB61**	5604	1	1			27.9
	FLYT62	5602	**HARB62**	5605	1	1			27.9
	HARB61	5604	**HARB62**	5605	5	-			
	HARB61	5604	**SC2360**	5606	1	1			87.0
	SC2360	5606	**SC2370**	5003	2	2			80.3

Key to circuit types
1=ohl
2=tx
3=cable
4=composite cct (ohl + cable)
5=bus section switch

Outages. The installation of even the minimum renewable generation scenario will have beneficial effects on system performance under single circuit outage conditions. There will be a general improvement in voltage levels that will eliminate the majority of those cases that resulted in voltages of less than 0.9 per unit[14]. A reduction in circuit utilisation with minimum renewables in service will eliminate overloading and low voltage problems in a number of cases, notably:

i) Some of the offending outage cases associated with the Blyth – Alcan - Linton circuits.

ii) The overloads on the Toronto 132/66 kV transformers.

iii) The overloads on the Hartmoor 275/66 kV transformers.

iv) The overloads on the Lackenby 275/66 kV transformers.

The increase in renewable generation associated with the moderate renewable scenario only marginally improves voltage levels and reduces the overloads and is not seen to effect any significant improvement.

However, with the maximum renewable scenario a significant improvement in system performance under outage conditions is evident with supplies in the Blyth area. System studies had shown that by 2009/10 the Blyth 275/132 kV and 275/66 kV transformers and the Blyth - Alcan – Linton 132/66 kV circuits could be subject to overloading and reduced voltages under single circuit outage conditions, which would require some reinforcement and re-configuration of the network to avoid the problems. However, with the 75 MW of renewables embedded in the Blyth area overloading and voltage problems would be eliminated providing their availability could be relied on when the system is operating close to peak demand (i.e. during the evening peak in an average cold spell in January or February). The maximum renewable scenario has less effect elsewhere, although again overloading and voltage levels will generally improve on those obtained compared with the minimum and moderate generation scenarios. Table 5.4 summarises the system performance under single circuit outage conditions for 2003/04 and 2009/10 for the various renewable generation scenarios.

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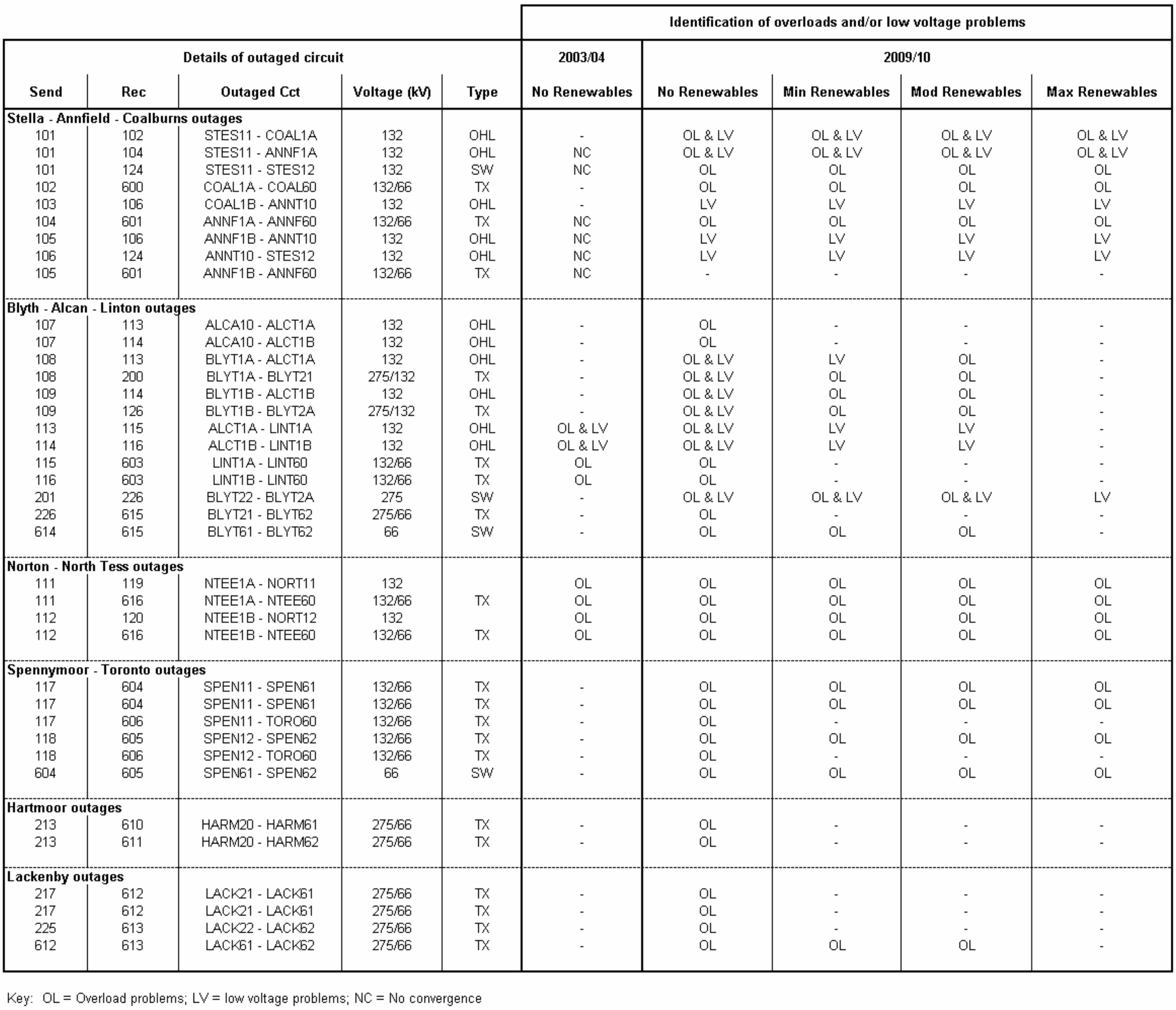
[14] In load flow analysis voltages are referred to as a per unit or percentage quantity. For example, a voltage of 0.9 per unit at a 132 kV busbar means that the actual voltage at this location is 132 x 0.9 kV, i.e. 118.8 kV.

Table 5.4: Summary of single circuit outage cases with overload & voltage problems



					Identification of overloads and/or low voltage problems				
Details of outaged circuit					2003/04	2009/10			
Send	Rec	Outaged Cct	Voltage (kV)	Type	No Renewables	No Renewables	Min Renewables	Mod Renewables	Max Renewables
Stella - Annfield - Coalburns outages									
101	102	STES11 - COAL1A	132	OHL	-	OL & LV	OL & LV	OL & LV	OL & LV
101	104	STES11 - ANNF1A	132	OHL	NC	OL & LV	OL & LV	OL & LV	OL & LV
101	124	STES11 - STES12	132	SW	NC	OL	OL	OL	OL
102	600	COAL1A - COAL60	132/66	TX	-	OL	OL	OL	OL
103	106	COAL1B - ANNT10	132	OHL	-	LV	LV	LV	LV
104	601	ANNF1A - ANNF60	132/66	TX	NC	OL	OL	OL	OL
105	106	ANNF1B - ANNT10	132	OHL	NC	LV	LV	LV	LV
106	124	ANNT10 - STES12	132	OHL	NC	LV	LV	LV	LV
105	601	ANNF1B - ANNF60	132/66	TX	NC	-	-	-	-
Blyth - Alcan - Linton outages									
107	113	ALCA10 - ALCT1A	132	OHL	-	OL	-	-	-
107	114	ALCA10 - ALCT1B	132	OHL	-	OL	-	-	-
108	113	BLYT1A - ALCT1A	132	OHL	-	OL & LV	LV	OL	-
108	200	BLYT1A - BLYT21	275/132	TX	-	OL & LV	OL	OL	-
109	114	BLYT1B - ALCT1B	132	OHL	-	OL & LV	OL	OL	-
109	126	BLYT1B - BLYT2A	275/132	TX	-	OL & LV	OL	OL	-
113	115	ALCT1A - LINT1A	132	OHL	OL & LV	OL & LV	LV	LV	-
114	116	ALCT1B - LINT1B	132	OHL	OL & LV	OL & LV	LV	LV	-
115	603	LINT1A - LINT60	132/66	TX	OL	OL	-	-	-
116	603	LINT1B - LINT60	132/66	TX	OL	OL	-	-	-
201	226	BLYT22 - BLYT2A	275	SW	-	OL & LV	OL & LV	OL & LV	LV
226	615	BLYT21 - BLYT62	275/66	TX	-	OL	-	-	-
614	615	BLYT61 - BLYT62	66	SW	-	OL	OL	OL	-
Norton - North Tess outages									
111	119	NTEE1A - NORT11	132		OL	OL	OL	OL	OL
111	616	NTEE1A - NTEE60	132/66	TX	OL	OL	OL	OL	OL
112	120	NTEE1B - NORT12	132		OL	OL	OL	OL	OL
112	616	NTEE1B - NTEE60	132/66	TX	OL	OL	OL	OL	OL
Spennymoor - Toronto outages									
117	604	SPEN11 - SPEN61	132/66	TX	-	OL	OL	OL	OL
117	604	SPEN11 - SPEN61	132/66	TX	-	OL	OL	OL	OL
117	606	SPEN11 - TORO60	132/66	TX	-	OL	-	-	-
118	605	SPEN12 - SPEN62	132/66	TX	-	OL	OL	OL	OL
118	606	SPEN12 - TORO60	132/66	TX	-	OL	-	-	-
604	605	SPEN61 - SPEN62	66	SW	-	OL	OL	OL	OL
Hartmoor outages									
213	610	HARM20 - HARM61	275/66	TX	-	OL	-	-	-
213	611	HARM20 - HARM62	275/66	TX	-	OL	-	-	-
Lackenby outages									
217	612	LACK21 - LACK61	275/66	TX	-	OL	-	-	-
217	612	LACK21 - LACK61	275/66	TX	-	OL	-	-	-
225	613	LACK22 - LACK62	275/66	TX	-	OL	-	-	-
612	613	LACK61 - LACK62	275/66	TX	-	OL	OL	OL	-

Key: OL = Overload problems; LV = low voltage problems; NC = No convergence

In 2003/04 the power exported south from Lackenby and Norton 400 kV grid stations under peak load (i.e. base case) conditions was around 900 MW. By 2009/10 with Seal Sands in operation and the interconnector with Norway in service the power exported south will increase to about 1600 MW with no renewables in service. The power exported south with the renewables added to the existing conventional stations in 2009/10 will increase to a about 2800 MW with the maximum renewable generation scenario[15].

Double circuit outages on the 400 kV and 275 kV North East Grid do not cause overloading or voltage problems with either the minimum or moderate renewable generation scenarios. However, with the maximum renewable case an outage of the double circuit 400 kV line between Norton and Osbaldwick will increase the power flow through the 400 kV circuit between Seal Sands and Lackenby above the circuit rating to produce an overload of around

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[15] The power exported south in 2009/10 with the minimum and moderate scenarios will be in the order of 1900 MW and 2400 MW respectively.

15%. This occurs because the power exported south can only be supplied from Lackenby Grid Station and the power previously supplied directly from Norton has to be diverted through Seal Sands. In practice it is likely that in such an event the generation in the region could be constrained back to reduce the overload. Of course, if the generation is not at full output and/or the number of renewable schemes that are implemented are closer to the moderate scenario then the overload condition would probably be avoided at least in that year and for some years to follow.

Short-circuit fault levels. Table 5.5 summarises the effect of the application of renewable generation on 400 kV and 275 kV system fault levels. The table shows the switchgear rating at 400 kV and 275 kV busbars across the NGC transmission system in the region and NGC's estimate as presented in its 2003 Seven Year Statement of the maximum 3-phase r.m.s. break duty in 2003/04 and 2009/10. A comparison of the break duty and the switchgear rating gives an indication of the adequacy or otherwise of the installed switchgear's capacity. Table 5.5 also shows the results of our short circuit analysis, identifying the maximum 3-phase r.m.s. break duty in 2003/04 and 2009/10 with no additional renewables and also with the maximum renewable generation scenario in place in 2009/10.

The table shows good correlation between NGC's fault levels (for the "no renewable" cases) and the study's figures. Importantly the table shows the overall effect on 400 kV and 275 kV fault levels of adding renewable generation on the network will be to increase the switchgear break duty by less than 1 kA, except on the 275 kV busbars at Stella West and Blyth where the break duty will increase by 1.9 kA and 1.3 kA respectively. The fault level at these two busbars will, however, still be below the switchgear rating.

Overall, therefore the effect of renewable generation on the 400 kV and 275 kV fault level is judged to be minimal. The fault levels at relevant 132 kV and 66 kV busbars are presented in Table 5.6 for the same three study cases as given in Table 5.5. The short circuit levels at 132 kV and 66 kV are again minimally affected probably because the schemes, although in the main connected at 66 kV or 132 kV, are all connected to the system via transformers, the impedance of which will substantially reduce the fault current injected at the higher voltage level. The results do, however, show that the fault level on the 132 kV busbars at Norton exceed the current switchgear rating, but NEDL has plans in place to replace the 132 kV bulk oil switchgear at Norton by 2004.

Table 5.5: Effect of renewable generation on NGC transmission system maximum short circuit fault levels

			NGC SYS03 figures : 3-Phase RMS Break Current (kA)		STUDY RESULTS : 3-Phase RMS Break Current (kA)			
Busbar	**Voltage (kV)**	**SWITCHGEAR RATING 3-Phase RMS Break Current (kA)**	**2003 Existing system**	**2009 No renewables**	**2003 Existing system**	**2009 No renewables**	**2009 Maximum renewables**	**Comment**
BLYT21	275	40/32	22.3	22.47	23.3	22.4	23.7	
BLYT22	275	40/32	19.59	19.63	18.4	17.4	18.1	
FOUR20	275		11.42	11.45	11.8	11.6	-	
FOUR21	275		-	-	-	-	23.5	
FOUR22	275		-	-	-	-	23.5	
GRST21	275		23.33	23.97	23.6	24.7	24.8	
GRST22	275		29.06	29.89	28.4	29.3	29.7	
HARK21	275	40	16.7	17.05	18.0	18.1	18.5	
HARK22	275	40	16.49	16.58	14.9	14.9	16.3	
HARK40	400	50	18	18.09	18.9	19.0	19.3	
HARM20	275	31.5	24.59	25.32	24.5	25.1	25.8	
HATL20	275	40 / 32.5	34.45	37.11	**34.5**	**37.2**	**37.9**	Consistenmt with SYS03 figures and <40kA rating
HAWP20	275	32	28.89	25.66	-	-	-	
HAWP21	275	32	-	-	28.4	25.1	25.9	
HAWP22	275	32	-	-	28.4	25.1	25.9	
HAWP2A	275	32	-	18.54	-	18.7	18.8	
HAWP2B	275	32	-	19.44	-	19.0	19.4	
HAWP40	400		-	26.15	-	26.2	26.6	
HAWP4A	400		18.68	-	18.2	-	-	
LACK20	275	40 / 31.5	29.36	30.22	-	-	-	
LACK21	275	40/31.5	-	-	28.6	29.6	30.0	
LACK22	275	40/31.5	-	-	28.6	29.6	30.0	
LACK2A	275	40/31.5	22.99	23.62	23.2	24.3	24.4	
LACK2B	275	40/31.5	22.99	23.62	23.2	24.3	24.4	
LACK40	400	63	30.18	33.26	29.0	33.4	33.7	
NORT20	275	31.5	17.73	35.16	-	-	-	
NORT21	275	31.5	-	-	17.5	**33.2**	**34.1**	Consistent with SYS03. Exceeds switchgear rating when 275 kV bus solid
NORT22	275	31.5	-	-	30.2	**33.2**	**34.1**	Consistent with SYS03. Exceeds switchgear rating when 275 kV bus solid
NORT40	400	63	30.16	33.78	28.6	33.4	33.8	
OFFE20	275		25.59	24.35	25.1	23.5	24.2	
OSBA40	400	63	27.18	42.82	27.3	36.9	37.0	
SALH20	275	31.5	31.93	34.72	28.6	31.2	**31.8**	Fault levels below SYS03, but s/c level still exceeds 31.5 kA rating
SEAS40	400		-	32.73	-	33.2	33.5	
SPEN21	275		20.54	20.94	16.6	20.2	20.9	
SPEN22	275		16.81	20.81	20.1	20.2	20.9	
SSHI20	275	31.5	23.67	23.34	22.9	21.9	22.6	
STEW20	275	50 / 31.5	29.37	29.99	-	-	-	
STEW21	275	50 / 31.5	-	-	28.9	28.8	30.6	
STEW22	275	50 / 31.5	-	-	28.9	28.8	30.6	
STEW4A	400		11.98	12.09	11.8	11.8	12.1	
STEW4B	400		11.98	12.09	12.2	12.1	12.5	
THTO41	400	50	40.17	46.91	44.3	46.9	47.1	
THTO42	400	50	41.64	48.04	44.3	46.9	47.1	
TODP20	275	32	29.06	30.21	27.7	28.8	29.1	
TYNE20	275	32	21.89	21.78	21.7	20.9	21.7	
WBOL20	275	31.5	26.61	26.07	25.9	24.6	25.5	

Table 5.6: Summary of maximum 3-phase short circuit break duties on relevant parts of NEDL 132kV and 66kV system

				NEDL LTDS results	**STUDY RESULTS : 3-Phase RMS Break Current (kA)**				
Busbar name	**Bus No.**	**Voltage (kV)**	**SWITCHGEAR RATING 3-Phase RMS Break Current (kA)**	**Existing system 3-Phase RMS Break Current (kA)**	**2003/04 Existing system**	**2009/10 No renewables**	**2009/10 Minimum renewables**	**2009/10 Moderate renewables**	**2009/10 Maximum renewables**
STEN11	100	132	25	12	14.1	17.1	17.2	17.3	17.4
STEN12	110	132	25	12	14.1	17.1	17.2	17.3	17.4
STES11	101	132	25	12.1	14.1	17.1	17.2	17.3	17.4
STES12	124	132	25	12.1	14.1	17.1	17.2	17.3	17.4
COAL60	600	66	21.9	6.7	6.5	6.7	6.8	6.8	6.8
ANNF60	601	66	21.9	6.1	6.2	6.4	6.4	6.4	6.4
BLYT61	614	66	21.9	14.8	16	15.6	16	16.1	16.9
BLYT62	615	66	21.9	14.8	16	15.6	16	16.1	16.9
LINT60	603	66	21.9	5.1	5.1	4.2	4.7	4.7	5.1
ALCA10	107	132	15.3	12.5	15.4	7.8	8.1	8.1	8.3
SPEN11	117	132	15.3	9.8	12.4	12.5	12.8	12.9	13.1
SPEN12	118	132	15.3	9.8	12.4	12.5	12.8	12.9	13.1
SPEN61	604	66	21.9	9.1	9.8	9.8	9.9	10	10.1
SPEN62	605	66	21.9	9.1	9.8	9.8	9.9	10	10.1
TORO60	606	66	21.9	6.1	6.8	6.8	7.3	7.3	7.8
NORT11	119	132	**15.3**	14.8	**16.5**	**16.7**	**16.7**	**17.1**	**17.1**
NORT12	120	132	**15.3**	14.8	**16.5**	**16.7**	**16.7**	**17.1**	**17.1**
NTEE60	616	660	21.9	13.6	12.1	12.1	12.1	12.2	12.2
HAWP61	608	66	21.9	12.5	14.4	14.2	14.9	15.3	15.8
HAWP62	609	66	21.9	12.5	14.4	14.2	14.9	15.3	15.8
HARM61	610	66	21.9	10.4	9.9	9.9	10.1	10.5	11.1
HARM62	611	66	21.9	10.4	9.9	9.9	10.1	10.5	11.1
LACK61	612	66	21.9	16.5	14.5	14.6	14.8	14.8	15.3
LACK62	613	66	21.9	16.5	14.5	14.6	14.8	14.8	15.3

5.6 System study conclusions

The connection of substantial amounts of renewable generation to the North East Grid will, with one or two exceptions, reduce the power flowing through the grid. This will lower system utilisation[16] and be beneficial in eliminating some of the potential overloads and low voltage conditions that can arise under outage conditions. Of particular note is the benefits obtained from coastal based schemes embedded in the NEDL system which can delay the need for reinforcement at the grid stations at Blyth, Hartmoor and Lackenby.

The connection of renewable generation to supplement the conventional stations will, unless the output from conventional stations is constrained, significantly increase the power exported south from the region. Consequently the utilisation on the 400 kV system in the south of the region will be substantially increased, such that with the maximum generation scenario there is the possibility of an overload condition on the Seal Sands – Lackenby 400 kV circuit in the event of an outage of the 400 kV Norton – Osbaldwick double circuit line.

The power flow studies have also shown that a major wind-farm north of Kielder generating up to 500 MW can be efficiently connected into the system at a point on the 275 kV system between Stella West and Harker grid station in Cumbria. In our analysis we identified the 275 kV substation at Fourstones, near Hexham, as the closest connection point. However, this would require a double circuit 275 kV overhead line to be routed through the Northumberland National Park to connect the scheme to the Fourstones substation, which could have significant visual impact. Nevertheless the scheme is sound technically and a compromise arrangement would be to run the 275 kV line from the wind-farm along the route of the existing Kielder – Spadeadam 33 kV line either to intercept the 275 kV circuits routed from Stella and Blyth to Harker, or else route the circuits all the way to Harker.

The impact of the renewable generation on system short circuit levels has been shown to be minimal and is unlikely to result in the need for a re-configuration of the network.

Overall the general impression obtained from the analysis is that the connection of renewable generation on the network will generally improve the technical performance of the electricity grid supply system in the north east of England over the next few years, although factors such as marginal increases in fault level and increased loadings on the two Yorkshire lines will need to be kept under observation.

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[16] Lower plant utilisation means that the equipment is operating at a lighter load and this can be beneficial in the long term as it can result in a longer operational lifespan.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Capacity to accept new generation

The modelling results reported in section 5 indicate that the grid in the region is generally able to handle the levels of renewable generation under consideration. Where there are potential future weaknesses these would exist even in a "no-renewables" scenario, and in some cases the connection of local generation in the form of renewables will be of benefit to the system.

The renewable generation areas can be broadly described in 2 groups – those along the coast where local load is high and generation will supply local demand (i.e. will be truly embedded), and those more remote areas where power will need to be exported via the distribution or transmission networks. The connection of these remote generating areas to the grid will require significant new infrastructure, as described in section 4.

These connections will be required under all the different scenarios (low, medium and high levels of generation) described in section 5. This is because generation at all these levels will need a connection to 33 kV or higher voltages, rather than the local 11 kV or 20 kV networks available in the remote areas of the region. Since in most cases we have suggested connection to the nearest point on the grid, the possibility to connect at lower voltages will make no difference to the length of connection required. Lower levels of generation may, however, allow for a cheaper connection due to the lower power rating required of the equipment.

6.2 Connection of Kielder

The connection of 500 MW of wind capacity at Kielder appears feasible. Various alternative routes to reach the 275 or 400 kV transmission network have been discussed in this report, with the shortest following the North Tyne down to Fourstones substation on the Harker-Stella 275 kV line. This route, and the alternative to meet the same 275 kV line further west, would have to cross either the Northumberland National Park or Hadrian's Wall.

The most appropriate solution is therefore likely to be option (a) described in section 4.2, i.e. to follow the route of the existing 33 kV line from Kielder to Spadeadam, and existing 132 kV line from Spadeadam to Harker. While this is a more expensive option (£28 million vs. £14 million), the presence of existing overhead line routes should minimise any added visual impact from the new connection. The capital cost represents 7.5% of the capital for a 500 MW wind farm [17], which is in-line with typical costs for a wind project. Should the total capacity be significantly less than 500 MW, however, the cost of a 275 kV connection may become prohibitively expensive, and solutions to connect at 132 kV would need to be examined. Whatever the total capacity, if a series of separate developments emerge within the Kielder area, some coordination would probably be required between projects to share the connection cost.

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[17] Assuming a total capital cost of £750/kw installed

Discussions with NEDL have indicated that a small number of remote consumers are currently supplied from the 33 kV Kielder to Spadeadam line. This will need to be taken into account in any upgrading of this line.

6.3 Connection of small wind in central Northumberland

We were asked to consider whether a new substation on the 400 kV interconnector running through central Northumberland could be used to exploit the wind resource in this area. This was done in the context of the sensitive landscape allowing only small wind turbine clusters.

Results are reported in Appendix C, our conclusion being that at least 10 small wind clusters (3 turbines each) would be required within a 10 km radius to be able to support the cost of such a substation. Alternative means of connection via the local 20 kV network were not assessed at this stage.

6.4 Recommendations

- There is no necessity to include grid capacity as a constraint in the overall Regional Renewables Strategy, assuming the generation assumptions and connection proposals used in this report remain valid.

- Geographical grid location relative to the generation areas is a constraint, in the sense that new connections need to be built. The necessary connections should be included as an integral part of the overall Strategy, i.e. recommended areas for renewable generation should include the routes of the power lines required to reach the grid.

- Each renewable generation area contains more than one individual project. Consideration should be given as to how the building of new grid connections for these projects could be co-ordinated. As well as allowing costs to be shared between projects, this would avoid multiple connections being brought forward when a single new line could provide the necessary link to the grid.

- A detailed assessment should be conducted of the 20 kV network in central Northumberland, to understand its capability to connect dispersed small wind turbine clusters, allowing the wind resource in this area to be exploited.

CONTENTS

Page No.

SUMMARY

APPENDIX A – MAPS
APPENDIX B – KIELDER WIND AREA
APPENDIX C – CONNECTION IN CENTRAL NORTHUMBERLAND

GOVERNMENT OFFICE FOR THE NORTH EAST

NORTH EAST OF ENGLAND RENEWABLE ENERGY STRATEGY – EXAMINATION OF GRID CONNECTIONS

NEREG/2003/007

JUNE 2003

PB POWER

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NEREG report final.doc

APPENDIX A

MAPS

The attached map shows the identified renewable generation areas, relevant parts of the transmission and distribution networks and potential routes for the new connections required for the more remote generating areas.

Dashed lines indicate the routes for new connections. Two options for connection of Kielder are shown – only one of these would be required.

APPENDIX B

KIELDER WIND AREA

A total wind capacity of 500 MW in the Kielder area implies 250 x 2 MW turbines. The land area this represents can be estimated using the following assumptions:

Turbine height to tip = 120 m
Turbine diameter = 80 m
Turbine spacing in predominant wind direction = 7 diameters
Turbine spacing across predominant wind direction = 3 diameters

In a block of 16 x 16 turbines, this would form a rectangle 3.6 km by 8.4 km. Clearly this is unlikely to be the actual configuration, given the complex terrain, wind speed and other constraints that will apply.

Each turbine can be allocated an average footprint based on this spacing, giving an area of 0.13 km^2 required by each turbine. On this basis, 250 turbines would require around 34 km^2.

In this study we have assumed that the principal area available for turbines would be north of Kielder Water, as this avoids MoD Spadeadam EWTR low-flying zone, though not the Tactical Training Area. For this reason we have assumed the transmission line running to a nominal point north of the lake. Very recent discussions between TNEI and the MoD, however, have indicated that no firm distinction should be drawn between the two MoD areas, which may open up possibilities on the south side of the lake.

In reality, any large-scale wind development at Kielder is likely to be made up of several groups of turbines, placed where constraints and wind resources allow, which would require several smaller connections into the main transmission line. Defining the locations of these groups is beyond the scope of this study, and the single line has been retained as a reasonable approximation at this stage.

APPENDIX C

CONNECTION IN CENTRAL NORTHUMBERLAND

The 400kV transmission line connecting to Scotland runs through central Northumberland, following an approximate route of Wylam-Belsay-Rothbury-Wooler-Coldstream (see map in Appendix A). There are areas of wind resource along this route, but no existing 400 kV substations to connect to, and no distribution grid above 20 kV nearby. PB Power was requested to assess the potential to create a new 400 kV substation along this route for the connection of wind generation. While no specific location has been assumed for the substation, the area between Belsay and Glanton appears to be the most promising in terms of constraints, although a site further north might offer greater opportunities to strengthen the local grid.

The cost of such a substation would be approximately £ 3 million [18], and only a substantial wind farm development would be able to justify this for a single project. From work carried out for the overall Regional Strategy, this sensitive landscape area only has scope for small clusters of wind turbines (e.g. groups of 3). We have therefore analysed the opportunity for several small projects to share the cost of creating this connection.

We have assumed an average project-to-substation distance of 10 km. This allows for an adequate area around the substation to locate turbine clusters. A significantly greater average distance is unlikely given the proximity of the National Park in the north, and alternative connection options along the coast and to the south. A greater distance also increases the cost of the line to connect to the substation, reducing the capital available to invest in the 400 kV substation. We have also assumed that up to 10% of the capital cost of each project could be allocated to the grid connection.

On this basis, the new substation could be justified by 10 or more small wind clusters (see below for assumptions and calculations), representing about 60 MW of total capacity This assumes that developers will prefer this approach to connection to the local 20 kV distribution network. Care would need to be taken in siting projects to avoid cumulative visual impact.

It is noted that the “clustering” of projects required to justify a 400 kV connection is not in keeping with the “dispersed” approach being proposed by the overall Regional Strategy. An alternative approach would be to develop a way to use the local 20 kV distribution grid to connect these projects, allowing greater dispersion throughout the area.

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[18] From PB Power’s knowledge of typical projects costs in the sector

Assumptions

- Each project consists of 3 x 2MW turbines, i.e. 6 MW total
- Capital cost for a small cluster = £1000/kw
- Acceptable grid connection cost = 10% of total capital = £100/kw = £600,000 per project
- Average distance from project to substation = 10 km
- Projects will prefer to connect to a 400 kV substation than to the local 20 kV distribution network
- Projects connects to substation via 33 kV wooden pole overhead lines

- 400 kV substation cost = £ 3 million
- 33 kV switch bay and control panel cost (per project) = £ 80,000
- Overhead wooden pole 33 kV line cost = £ 20,000/km

Calculation

Each project will have to justify its share of the substation cost, plus the cost of the line connecting the project location to the substation.

After iteration, a solution of a minimum of 10 projects is reached, with the following costs:

> 400 kV substation cost allocation per project = £ 300,000
> Average overhead line cost (10 km) per project = £ 200,000
> Project switch bay cost = £ 80,000
> Total cost per project = £ 580,000

This falls within the defined 10% limit, suggesting that 10 schemes of 3 turbines each could jointly justify a new substation on the 400 kV line.

LIST OF REVISIONS

Current Rev.	Date	Page affected	Prepared by	Checked by (technical)	Checked by (quality assurance)	Approved by
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