New Approaches for Identification of Required Transmission Capability: Progress Report

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Executive Summary

The authors of this note feel that the criteria underlying approaches 3 and 4 are essentially sound and either of them might be regarded by electricity supply industry stakeholders as providing a rational, clear and unambiguous basis for investment in transmission. However, in view of the requirement that any new MITS planning rule should not deliver less reliability of supply than that presently delivered, we feel that a suitable basis for a new MITS planning rule might be that the required transmission capability should be (i) that determined for the satisfactory meeting of peak demand for electricity; or (ii) that determined by the provision of equal access to the market for generation; or (iii) that determined by an economic evaluation, whichever of these three is the greatest.

The re-characterisation of approach 3 that we have recently undertaken seems to us, based on what we have been able to do so far, to be sufficiently good provided there is agreement on suitable assumptions for ‘typical’ conventional generation unit size and availability. Further work is required to develop a complete characterisation for approach 4, though results so far seem promising in that there would indeed appear to be smooth relationships in the problem space.

We feel reasonably confident that 3 man-months’ further work on approach 4 would give good indications on its prospects for inclusion in a revised GB SQSS in the next 6-12 months.

1 Introduction

At the public workshop on the GB Security and Quality of Supply Standard (GB SQSS) in Birmingham on January 10th 2008, the transmission licensees outlined 5 main approaches to the identification of the required level of capability on the GB main interconnected transmission system (MITS). Furthermore, in launching a consultation on the 5 approaches, opinions were invited by February 22nd 2008. However, it was also noted that two of the approaches – 'approach 3' represented by a set of 'membranes' characterising transmission capability required to satisfy a reliability criterion and 'approach 4' based on a criterion concerning the provision of equal access for generation to demand on the transmission system – were 'work in progress'.

As requested at the January 10 workshop, this document summarises recent progress on approaches 3 and 4. While some brief background is given, it should be noted that, since the work is not complete, it is not the intention at this stage to provide a full report on the approaches. This will be produced in due course.

The remainder of this document is organised as follows:

- a review of the background to approaches 3 and 4;
- a brief description of the tools and benchmarking methods used in developing approaches 3 and 4;
- a comparison of indicative required capabilities arising from approaches 3 and 4;
- a report on progress towards the development of relatively simple 'characterisations' of approaches 3 and 4;
- conclusions to date.

2 Background to approaches 3 and 4

This section summarises the background to approaches 3 and 4. Further background may be found in Keith Bell's presentation to the August 2007 GB SQSS workshop in Birmingham, available on National Grid's GB SQSS website.

While approaches 3 and 4 are based on different criteria, they have the same objectives which are our interpretation of the transmission licensees' concern, set down in the original project specification, to have a practical and easy to apply new MITS planning criterion:

1. to provide a simple, accurate and reliable means of identifying the required secure power transfer capability across boundaries of the main interconnected transmission system (MITS) in Britain;
2. to depend on the input of no more data than the equivalent MITS capability method in the present GB SQSS requires.

In addition, we believe the approach should be robust against feasible changes to the generation and demand background in the next 10-15 years so minimising the likelihood of a further review of the MITS planning criterion being required in that period.

One of the requirements identified by the transmission licensees for a new MITS planning criterion was that it should deliver no worse a reliability of supply than the current approach. This requirement has formed the basis of 'approach 3' starting with 'benchmarking' of the current approach in reliability terms, specifically the range of minimum imports of power into an area necessary to meet demand in that area. This central idea was first suggested in the transmission licensees' original project specification. It was subsequently used to underpin investigations at the University of Bath and at Imperial College. We have also used it, though the precise means we have used to perform that benchmarking are different from those used elsewhere. These are briefly described in section 3 below.

The criterion upon which approach 4 has been based is founded on three things:

1. the obligation that the transmission licensees have to facilitate competition in generation;
2. the encapsulation by the 'planned transfer' and 'effective generation' in the present MITS design criterion of a condition representing a view of the despatch of 'contributory' generation that takes account of relative availabilities of power from different generation technologies but which is unbiased – 'market neutral' – in respect of commercial positions;
3. the fact that the x-axis value of the 'circle diagram' in appendix D of the GB SQSS depends on both generation and demand in an area thus providing transmission capability into or out of both an area containing only generation and an area containing only demand.

The second and third of the above three observations suggest to us that the present standard is not only concerned with the reliable meeting of demand but also with the facilitation of system access for generation. Taking into account the first observation as well, we therefore suggest that 'approach 4' might be concerned with "the facilitation of equal access to the market for generation, proportional to its ability to exploit it". Furthermore, this might be understood with respect to the range of 'scaled transfers' across a boundary where a 'scaled transfer' for any given pattern of demand and available generation is that which represents a 'market neutral' despatch of that generation to meet that demand.

Both the 'minimum import' into an area (upon which 'approach 3' is based) and the 'scaled transfer' across a boundary (upon which 'approach 4' is based) are stochastic quantities influenced by uncertainty in demand and the availability of generation. A transmission planner might perform a detailed probabilistic assessment – such as required in 'approach 2' – of the required boundary capability for any given background of peak demand and generation capacity, either by 'analytical' or simulation methods. However, noting objectives 1 and 2 above, we have sought to characterise the underlying relationships between the stochastic variables to provide a (relatively) simple function – or 'recipe' – that the transmission planner – or anyone else – might apply. Our progress to date in seeking suitably accurate characterisations is summarised in section 5.

3 Assessment tools and benchmarking

We have developed two main assessment tools for this work:

- a 'specific' simulation engine that, given detailed data on demand uncertainty, zonal locations of demand and generation, generation types, unit sizes, availabilities and – for wind generation – terrain types, calculates[1]the distributions of minimum, maximum and 'scaled' transfers across defined boundaries at time of system peak demand and, given benchmark values for minimum import and scaled transfers, calculates required boundary capabilities for N-1 and N-2 for approaches 3 and 4. (Figure 1).
- a 'generic' simulation engine that, given benchmark values for minimum import and scaled transfers, calculates N-1 and N-2 required transfers for approaches 3 and 4 for a specified wide range of possible scenarios. (Figure 2).

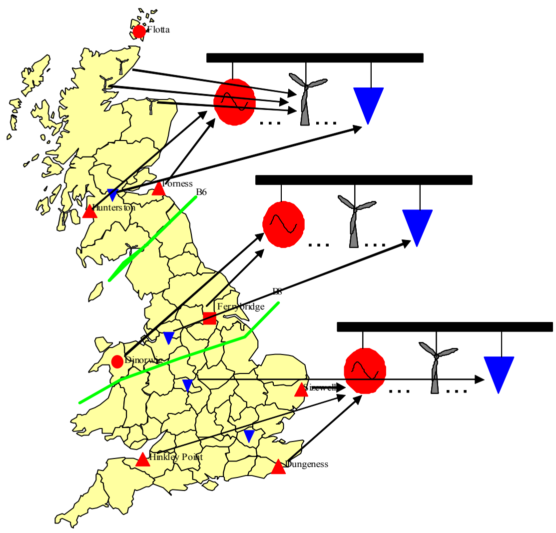

Figure 1- 'Specific' simulations: actual generation types, capacities, locations and availabilities in a scenario are simulated and zonal demand sampled to find imbalances between available generation and demand in each zone

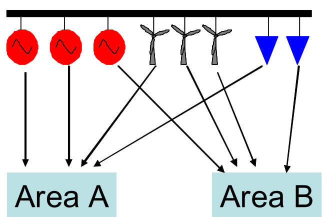

Figure 2- 'Generic' simulations: demand, a set of 'typical' wind farms and a set of similar conventional generators are simulated and subsequently allocated in a range of different combinations to two areas for which imbalances between demand and available are calculated

[1] Strictly speaking, a Monte Carlo simulation approach such as we have used gives only an estimate of any given statistic. However, if the number of trials in a simulation is sufficiently large, the estimate can be a very good one. Indeed, because of the way in which the detailed characteristics of the modelled system can represented in a simulation compared with the approximations that might be required in an 'analytical' approach, a simulation can often give a more accurate estimate than an 'analytical' approach.

Each of the above engines makes use of a quite detailed model of the wind power resource. This was previously developed by the University of Bath and Garrad Hassan and Partners Ltd. and involves a model of simultaneous 10m high wind speeds at 20 different locations across Britain, conversion to 10m high wind speeds at 'typical' wind farm locations in each of 20 different zones and 4 different terrain types, conversion to a hub height wind speed and finally conversion to electrical power output. For any given distribution of wind generation capacity among the 20 zones and 4 terrain types, the model is designed to respect the geographical correlation of wind speeds and thus accurately represent 'diversity' effects.

The use of generic simulations is described further in section 5 below.

The benchmarking of the present GB SQSS has been carried out separately for N-1 and N-2 security by assuming the boundary capabilities for the 2007/8 scenario published by NGET in July 2007 to be exactly equal to that required by the current standard. The probability of, for approach 3, the minimum import requirement or, for approach 4, the scaled transfer exceeding the boundary capability was then identified from a 'specific' simulation. The boundaries for which this was done were the Seven Year Statement (SYS) boundaries to which the current 'planned transfer' and 'interconnection allowance' rules apply, i.e. boundaries 4 to 17.

The results are shown in Figure 3 and Figure 4. It can be seen that the risk of not being able to accommodate the necessary transfers of power is quite different from one boundary to the next, thus making less than obvious what single, nationally representative 'benchmark' risk thresholds should be for N-1 and N-2 under each approach[2].

In order to identify suitable benchmark indices, we have calculated the root mean squared deviation between the required capability resulting from use of a particular benchmark and that required by the current standard, summed over all the SYS boundaries B4 – B17 for the 2007 scenario. For each of approaches 3 and 4, and for N-1 and N-2 security in each case, the RMS deviations were calculated for a range of different benchmark values. The benchmark value that has the lowest RMS deviation could then be identified for each case (see Figure 5 for N-1 and Figure 6 for N-2). These benchmark values are shown in Table 1[3].

Table 1 - benchmark risks: probability of the transfer exceeding the required capability

	Reliability-based (Approach 3)	Generation equal access-based (Approach 4)
N-1	0.05%	0.5%
N-2	0.5%	6%

[2] The observed variability is a consequence of the different populations and sizes of generation in different areas and the quite large variability of values towards the ends of distributions. While it could be argued that a different benchmark could be determined for each boundary, it is our opinion that that (a) would not be in the spirit of the original interconnection allowance and (c) would be over-directed towards just one moment in time and therefore unlikely to be a robust basis for future planning. We therefore favour identification of four 'national' benchmarks: for approach 3 for N-1 and for N-2, and similarly for approach 4.

[3] The result for N-2 for approach 3 compares with 0.45% for approach 2, itself based on an assumed 'single bus' loss of load probability (LOLP) of 9% and an increase in LOLP due to shortage of transfer capability on a boundary of 5% of the single bus LOLP. (The 'single bus' loss of load probability is that due to a simple shortage of available generation relative to demand on the system as a whole)

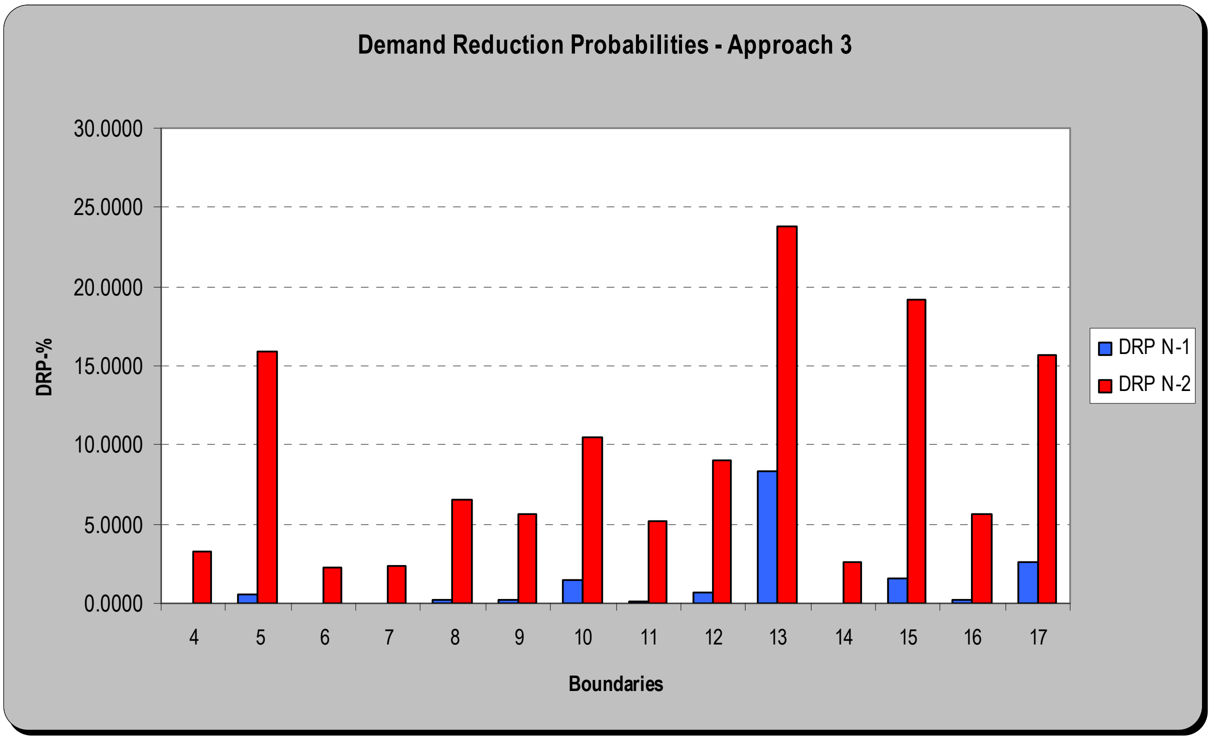

Figure 3- demand reduction probabilities (approach 3) for the NGET 2007/8 scenario with boundary capabilities equal to those required by the current Standard

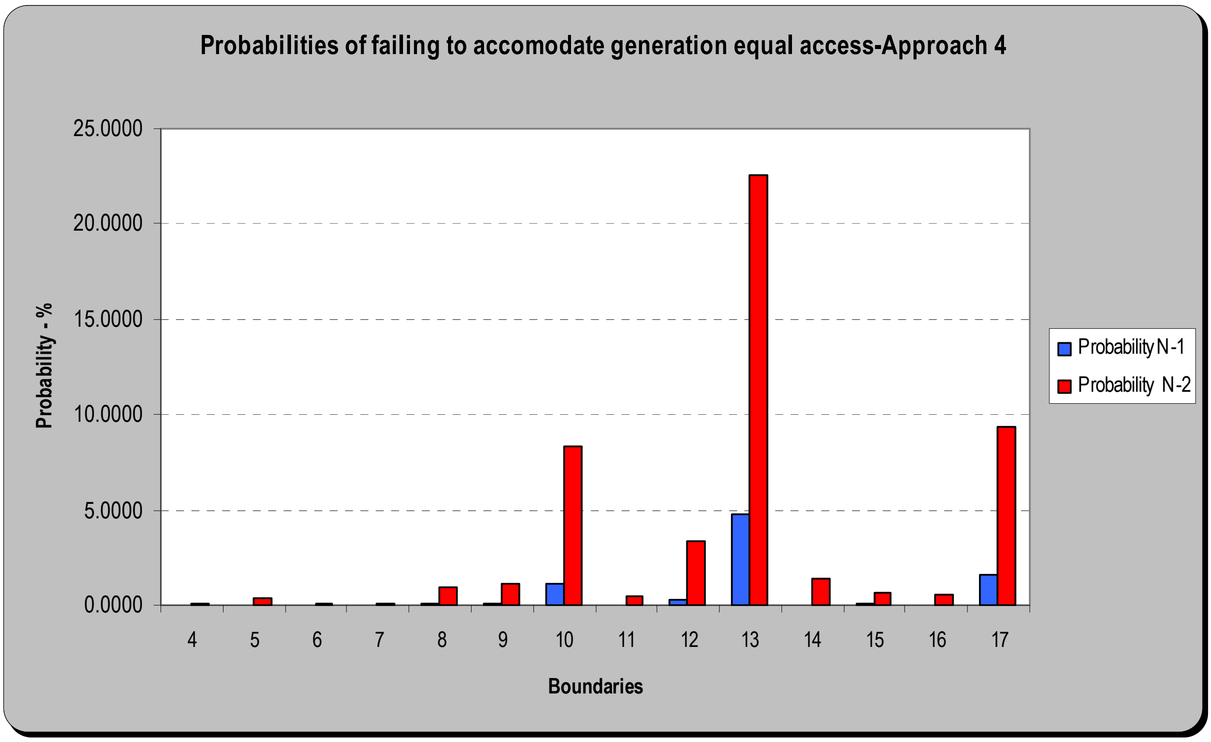

Figure 4 - probabilities of failing to accommodate generation equal access (approach 4) for the NGET 2007/8 scenario with boundary capabilities equal to those required by the current Standard

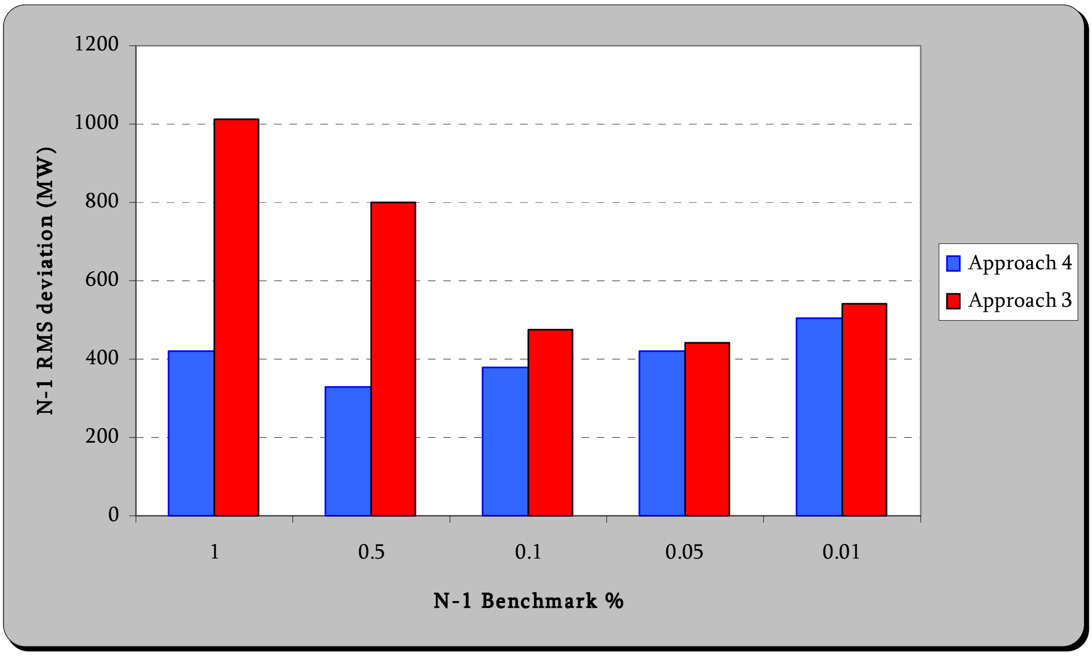

Figure 5 - RMS deviation minimisation for N-1 criteria

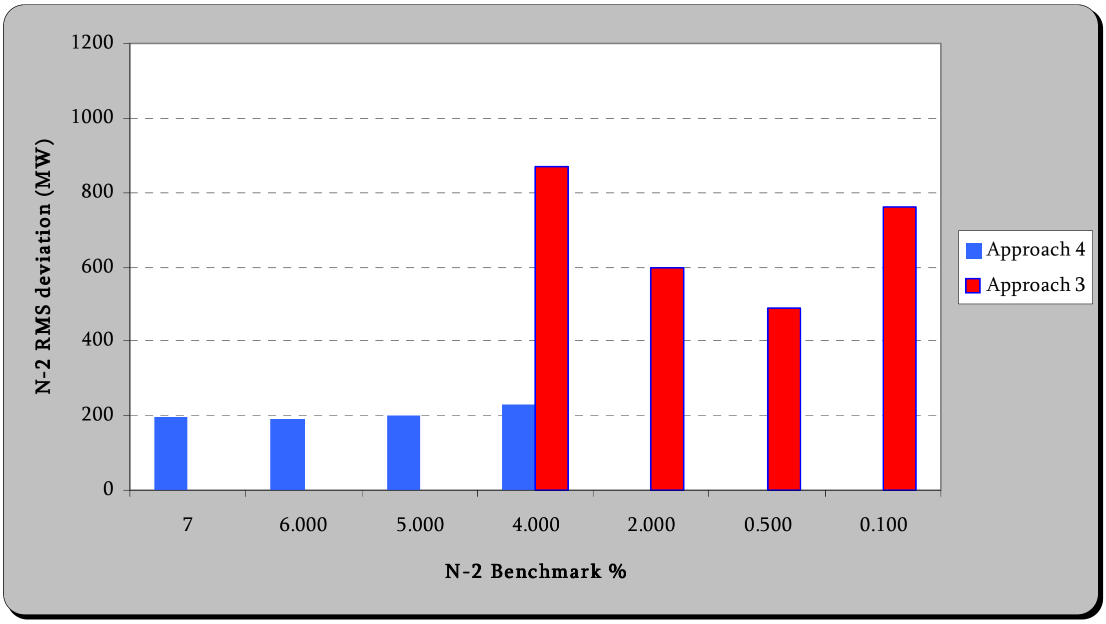

Figure 6 – RMS deviation minimisation for N-2 criteria

4 Indicative required capabilities arising from approaches 3 and 4

'Specific' simulations carried out by TNEI Services Ltd. and the University of Strathclyde and application of the benchmarks proposed in section 3 above have allowed the required future capabilities to be identified for the 2013/14 and 2020/21 scenarios published by NGET on the GB SQSS website in July 2007. These are compared in Figure 7 to Figure 9 with the approach 2 simulation results reported by NGET at the January 2008 workshop and those that NGET has reported would be required by application of approach 1(b) (a modified version of the current Standard).

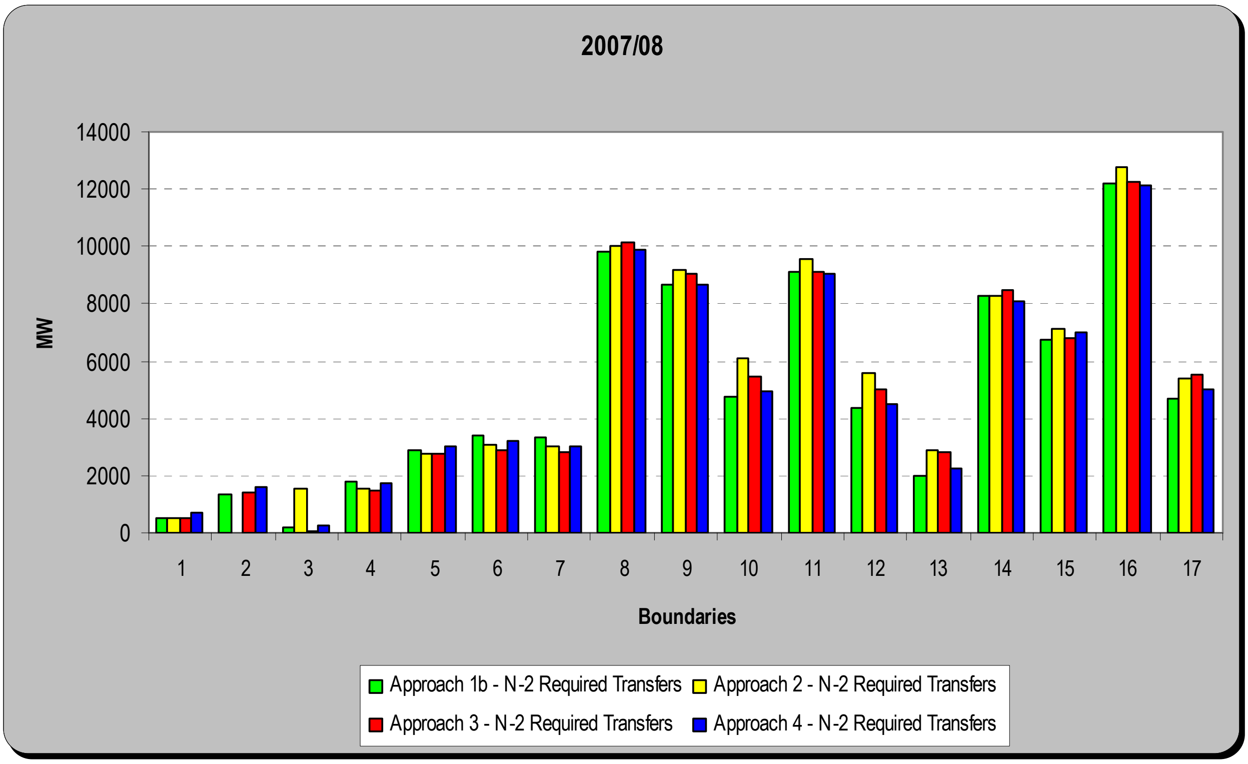

Figure 7- TNEI/Strathclyde specific simulation results for the NGET 2007/08 scenario and N-2 security

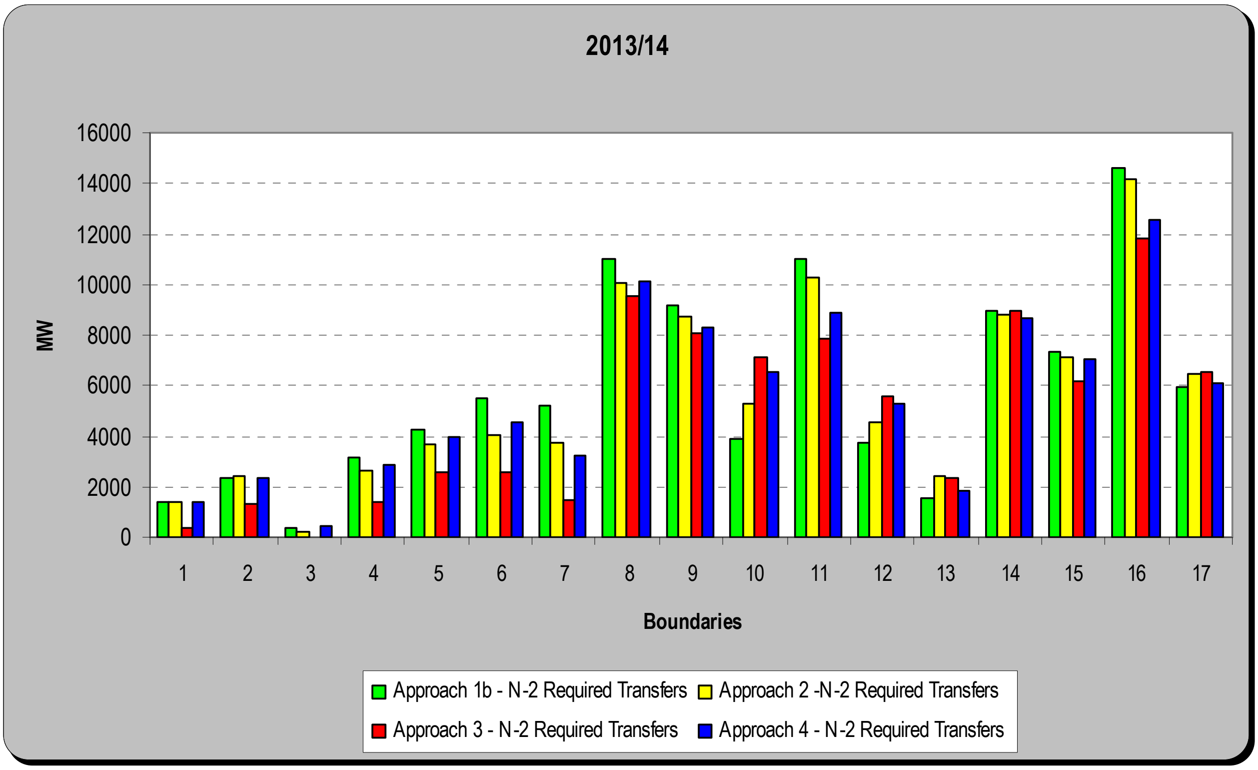

Figure 8 - TNEI/Strathclyde specific simulation results for the NGET 2013/14 scenario and N-2 security

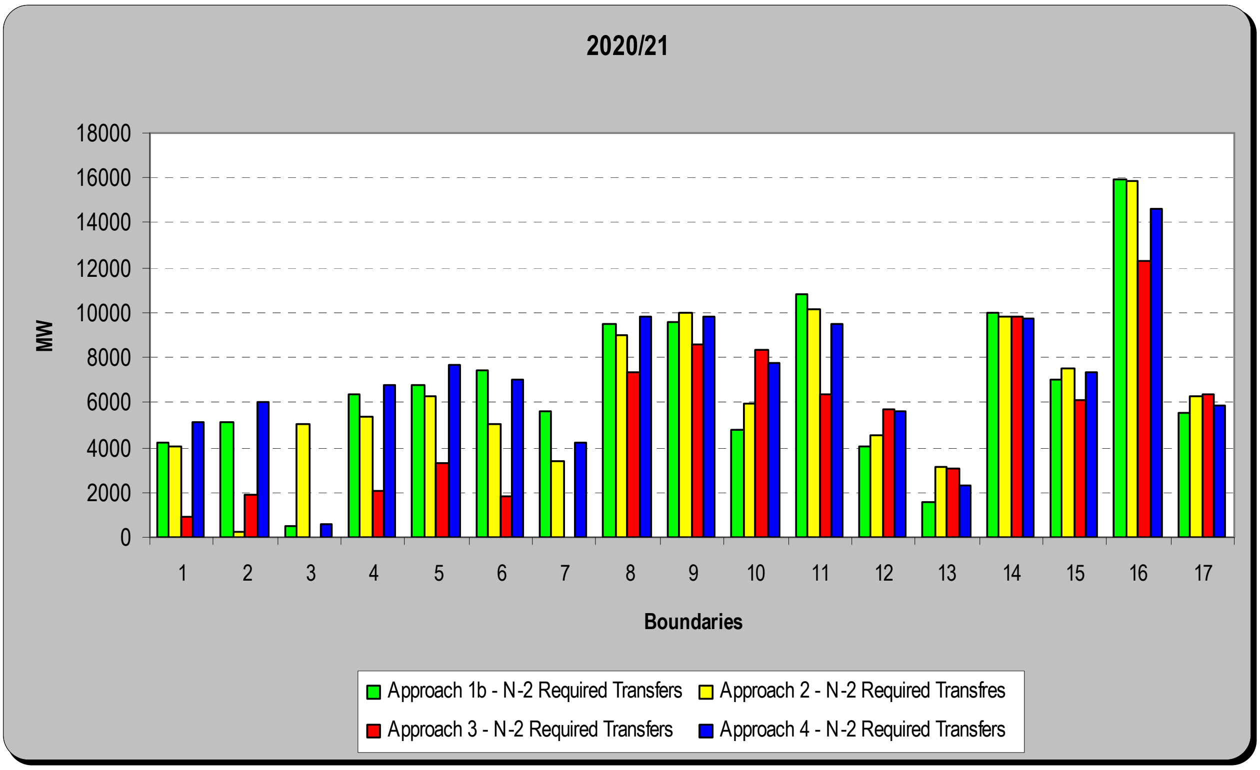

Figure 9 - TNEI/Strathclyde specific simulation results for the NGET 2020/21 scenario and N-2 security

It can be seen from Figure 7, Figure 8 and Figure 9 that, broadly speaking, approach 1b (a modified version of the current GB SQSS) has the highest required capabilities except for those boundaries that are characterised by one side having little generation capacity relative to demand in the area, e.g. B13 and B17. In these cases, the reliability based approaches – approaches 2 and 3 – have the highest required capabilities[4]. Between the two approaches that we are developing – 3 and 4 – it can be seen that approach 4 usually has the highest requirement; however, for some boundaries, approach 3 does. This observation – and the apparent change in the critical factor from one boundary to another between ensuring equal access for generation and the meeting of demand – is built upon in a suggestion outlined in 6.

[4] One might consider the cause of the differences in results between approach 2 as implemented by NGET and our 'specific' simulations of approach 3. While the approaches are based on comparable principles, the differences seem to us to be likely to be due to differences in modelling, of conventional generation and, in particular, wind generation.

5 Characterisation progress

This section reports progress made in seeking simple functions – effectively, characterisations of the relationships – for approaches 3 and 4.

A simple function based on a few inputs inevitably lacks some information that determines the 'real' position. However, it has seemed to us that suitable assumptions might be made for this information that represents 'typical' behaviour. These include:

- the uncertainty in demand associated with weather conditions at the time of annual system peak demand;
- the average winter afternoon/early evening availability of 'conventional' generation;
- the geographical area of a transmission group over which wind farms may be spread, the hub height wind characteristics of typical wind farm sites in that area, the wind speed to power conversion characteristics and the average unavailability of individual turbines.

In addition, for a general characterisation and in order not to increase the number of individual inputs to a general function that can be applied by a transmission planner, appropriate assumptions should be made for the following:

- the average size of conventional generating unit that would be subject to the most frequently occurring periods of forced outage;
- the availability of conventional units.

With suitable assumptions for the above, 'generic' simulations can be carried out to determine the required boundary transfer capability that would be consistent with the pre-determined risk benchmark. These can be set up to cover the entire feasible range of the inputs to an identification of required transfer capability that might be used by a transmission planner. The results permit an exploration of the relationships between the values of the inputs and that of the output – the N-1 or N-2 required transfer capability. If the relationships are sufficiently smooth and the number of generic simulations sufficiently large and well-distributed throughout the problem space, it should be possible to generalise them. This should in turn permit accurate interpolations between simulated points and so provide a simple, accurate and reliable means of identifying the required secure power transfer capability. This is what the characterisation work has sought to achieve, both for the reliability based 'membranes' (approach 3) and for 'generation equal access' (approach 4). However, as was acknowledged both at the January 2008 workshop and at previous SQSS meetings, while the approach has seemed highly promising, some detailed implementation issues remained. These, and the progress made in resolving them, are described briefly below.

5.1 Approach 3 – reliability based boundary capability

5.1.1 Origin

Between November 2006 and February 2007, some work was carried out at the University of Strathclyde to develop a set of generic simulations from which reliability-based required boundary capabilities might be identified, and to seek a suitably robust characterisation of those capabilities. Using some prototype software and a set of assumptions for demand uncertainty, unavailability of conventional generation and the geographical area that might be taken as representative of a transmission group delineated by a main system boundary, each of a very large set of combinations of input values was simulated. (See section 3 for a brief description of the 'generic' simulation approach used).

It proved possible to identify smooth relationships involving the following:

- the ACS demand in an area at time of system peak;
- the 'conventional' generation capacity in the area;
- the wind generation capacity the area;
- the required boundary import capability into the area.

This was done for both N-1 and N-2 secure boundary transfers and revealed a set of slightly bent planes – 'membranes' – in a space for which the axes were:

- the difference between ACS demand in the area and the total generation capacity in the area;
- the total generation capacity in the area;
- the required import capability.

The different membranes represented different ratios of wind generation capacity to the total generation capacity in the area.

In November 2007, TNEI Services Ltd. recoded the generic simulation software, making it considerably faster so that more cases might be evaluated. In January 2008, this has been applied to some revised assumptions and a more complete exploration of the problem space. The main results to date are reported in section 5.1.2 below.

5.1.2 Results

It can be seen from Figure 10 that the revised characterisation carried out by TNEI Services Ltd. and the University of Strathclyde succeeds in showing smooth relationships leading to the expectation of being able to provide a (relatively) simple function to transmission planners for identification of required transfer capability.

The 'base case' for the revised characterisation has been the following:

- conventional generating units of average size of 200MW represented by a 'two-state' model and availability of 88.6%;

- the wind resource represented as if it were made up of capacity in feasible locations north of boundary B7;
- a maximum demand reduction probability on any one boundary of 0.05% for N-1 and 0.5% for N-2.

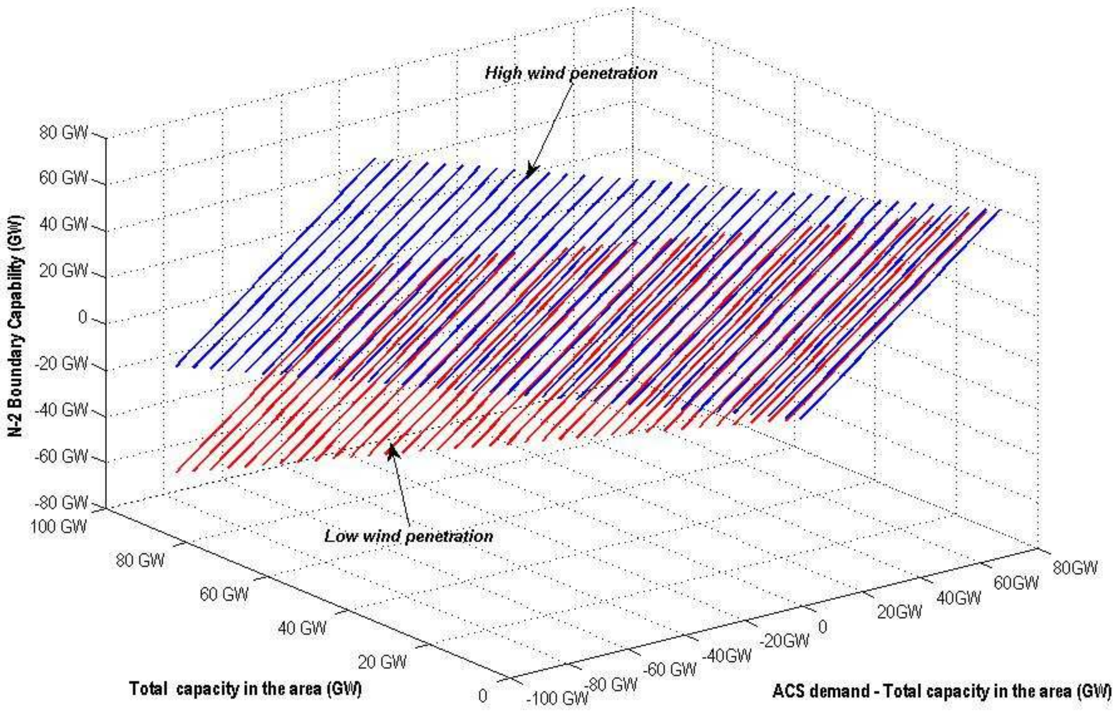

Figure 10 - view of the N-2 reliability-based characterisation

Two alternative characterisations have been developed based on the following sensitivities:

1. conventional generating units assumed to be each of 500MW with 88.6% availability;
2. conventional generation availability assumed to be 91% and of size 200MW.

The results of application of the characterisations[5] for the Seven Year Statement boundaries for the 2013/14 and 2020/21 scenarios published by NGET on the GB SQSS website in July 2007 are shown in Figure 11 to Figure 14. These can be compared with the specific simulation results shown above in Figure 7 to Figure 9. All these results for the reliability based approach are summarised in Table 2 and Table 3. Issues associated with the sensitivity analyses are discussed in section 5.3 below.

[5] To apply a characterisation to a particular scenario, rather than perform a detailed specific simulation of it, we have simply interpolated between points in the characterisation space.

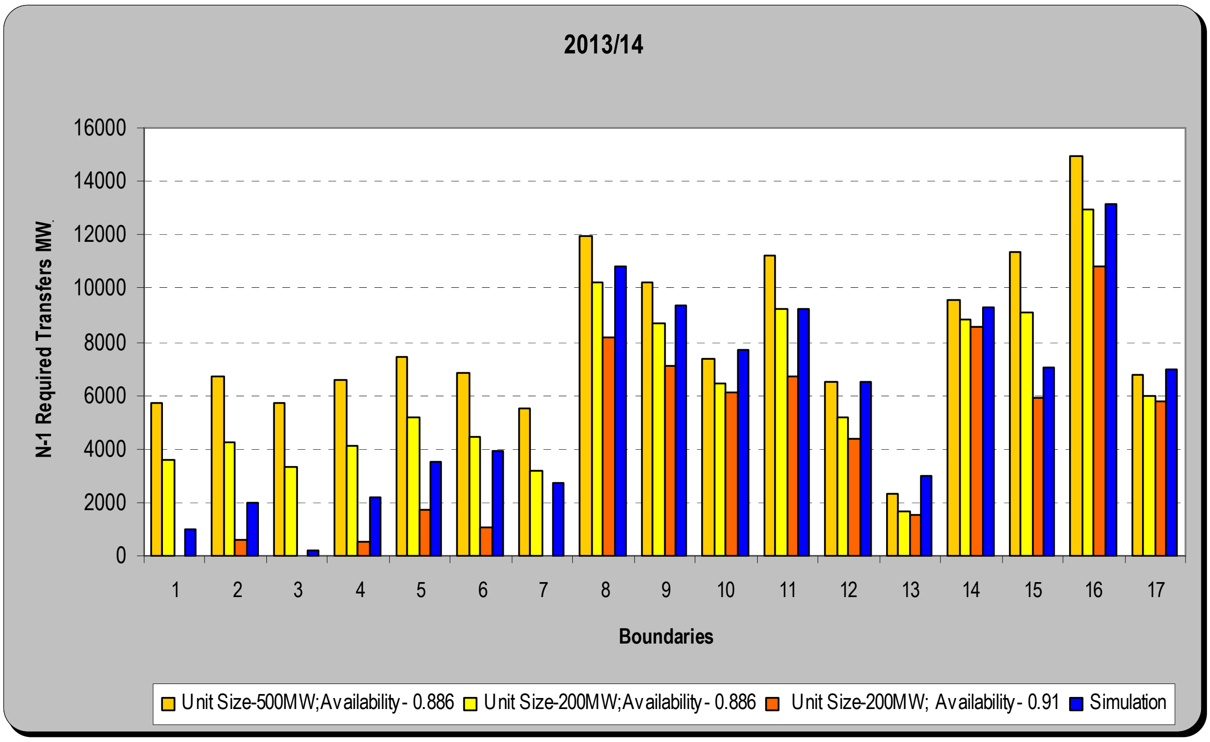

Figure 11 - results of application of the reliability-based characterisation to the NGET 20013/14 scenario and N-1 security

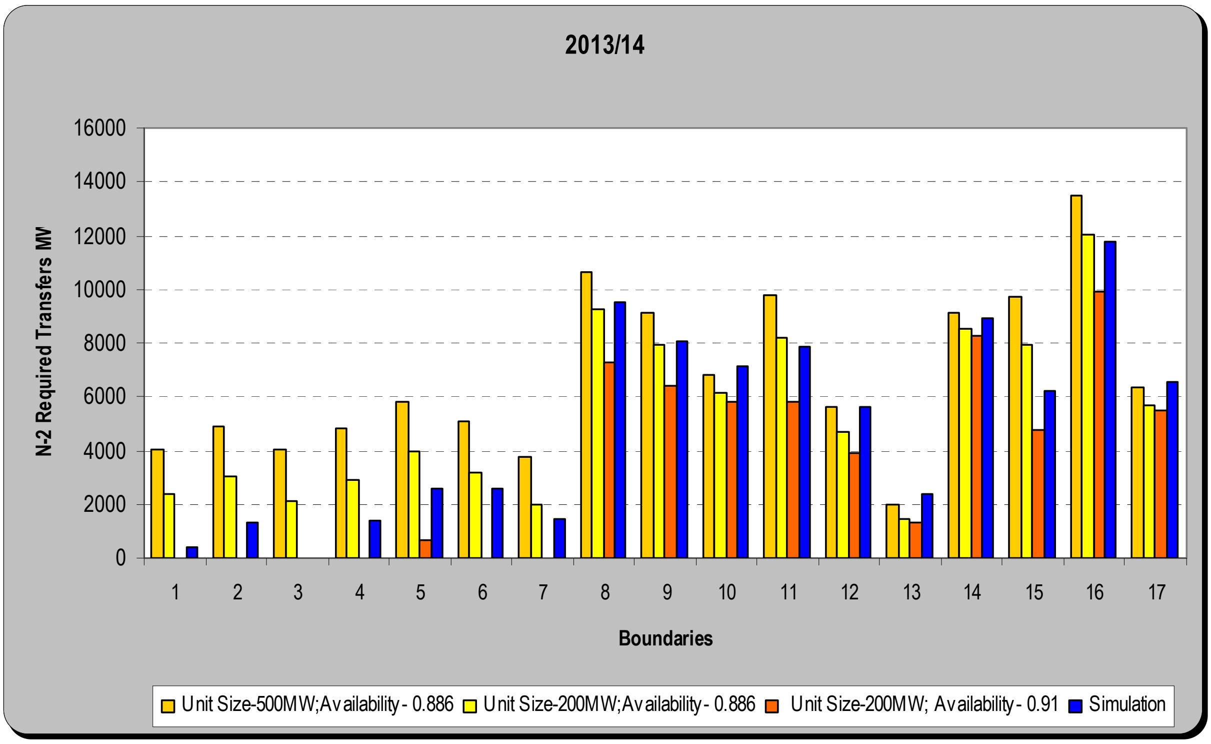

Figure 12 - results of application of the reliability-based characterisation to the NGET 20013/14 scenario and N-2 security

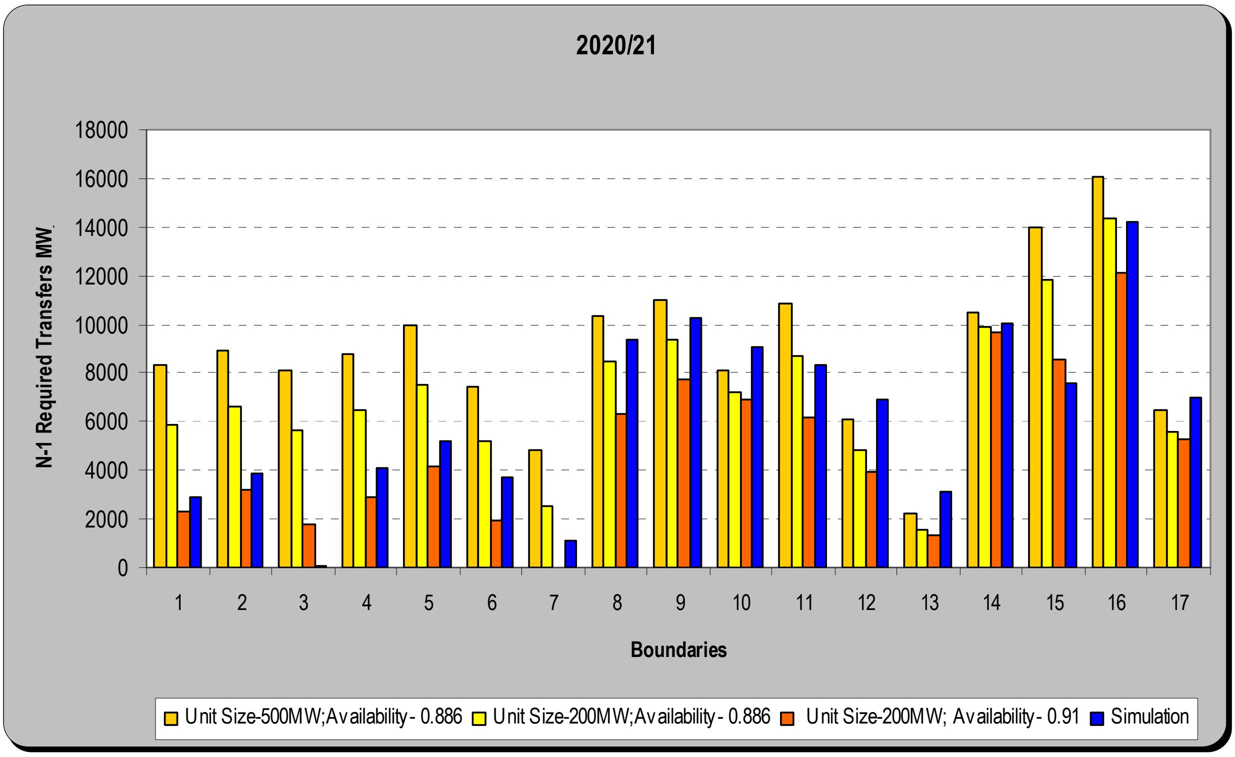

Figure 13 - results of application of the reliability-based characterisation to the NGET 2020/21 scenario and N-1 security

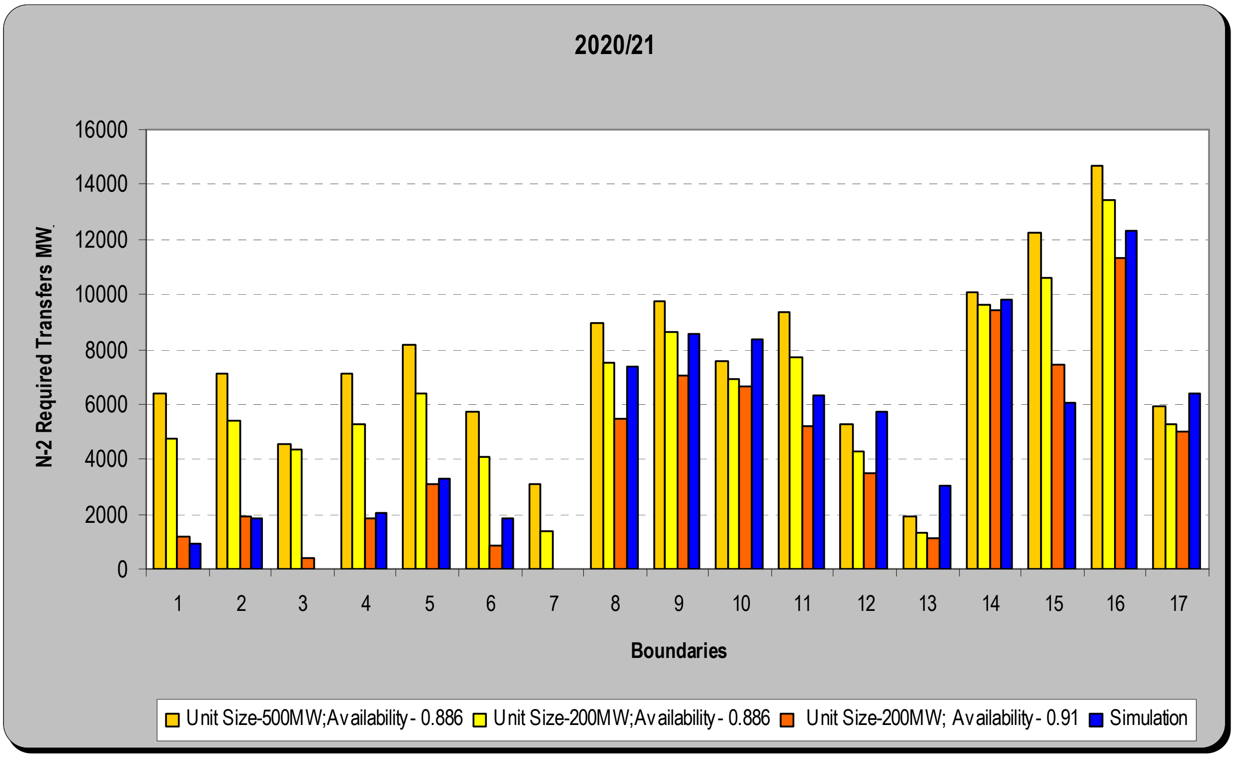

Figure 14 - results of application of the reliability-based characterisation to the NGET 2020/21 scenario and N-2 security

Table 2 - N-1 required capabilities based on reliability (approach 3)

	2013/2014				2020/21			
	Unit Size 500MW; Availability 0.886	Unit Size 200MW; Availability 0.886	Unit Size 200MW; Availability 0.91	Simulation	Unit Size 500MW; Availability 0.886	Unit Size 200MW; Availability 0.886	Unit Size 200MW; Availability 0.91	Simulation
1	5711	3575	0	995	8338	5899	2294	2920
2	6690	4264	584	1986	8898	6627	3163	3892
3	5696	3341	0	207	8080	5651	1797	48
4	6602	4119	508	2210	8806	6493	2933	4080
5	7468	5163	1717	3495	9931	7530	4132	5214
6	6854	4428	1093	3902	7433	5234	1905	3737
7	5526	3169	0	2748	4843	2559	0	1145
8	11975	10213	8144	10838	10358	8459	6340	9363
9	10235	8698	7090	9344	10984	9407	7767	10257
10	7369	6438	6098	7681	8082	7205	6914	9055
11	11188	9246	6694	9247	10875	8684	6204	8304
12	6536	5208	4360	6481	6125	4857	3961	6949
13	2351	1683	1511	2960	2257	1526	1332	3152
14	9585	8807	8571	9305	10474	9862	9689	10055
15	11337	9066	5902	7045	13996	11798	8588	7571
16	14963	12954	10853	13116	16090	14342	12135	14186
17	6774	5983	5750	6965	6436	5554	5269	6965

Table 3 - N-2 required capabilities based on reliability (approach 3)

	2013/2014				2020/21			
	Unit Size 500MW; Availability 0.886	Unit Size 200MW; Availability 0.886	Unit Size 200MW; Availability 0.91	Simulation	Unit Size 500MW; Availability 0.886	Unit Size 200MW; Availability 0.886	Unit Size 200MW; Availability 0.91	Simulation
1	4014	2359	0	385	6380	4714	1166	897
2	4886	3069	0	1290	7119	5399	1908	1859
3	4022	2087	0	0	4573	4338	423	0
4	4852	2935	0	1406	7090	5253	1837	2026
5	5815	3995	655	2569	8140	6369	3084	3273
6	5096	3194	0	2598	5699	4066	835	1838
7	3801	2014	0	1468	3115	1386	0	0
8	10636	9246	7285	9524	8976	7532	5445	7387
9	9113	7915	6392	8090	9757	8606	7034	8549
10	6838	6122	5820	7125	7570	6901	6635	8347
11	9767	8201	5794	7860	9327	7698	5232	6341
12	5650	4694	3930	5610	5242	4305	3499	5703
13	2015	1481	1311	2360	1888	1313	1124	3015
14	9106	8508	8287	8939	10075	9583	9421	9803
15	9731	7950	4749	6184	12236	10569	7441	6077
16	13503	12044	9912	11796	14708	13404	11294	12324
17	6321	5711	5492	6551	5941	5267	5005	6369

5.2 Approach 4 – generation equal access based boundary capability

The characterisation of approach 4 carried out in December 2007 and January 2008 by TNEI Services Ltd. and the University of Strathclyde has followed a similar methodology to that described in section 5.1 above. However, in view of approach 4's dependency on 'scaled transfers' and hence on available generation relative to demand on *both* sides of a boundary, it is expected to have many more degrees of freedom.

This would seem to make it impossible to be visualised completely in 3 dimensions, although, with further study by such means as independent components analysis that it has not yet been possible to undertake, it may turn out that only certain dimensions are significant.

Initial results show smooth relationships that suggest a good characterisation is possible. However, in what we have been able to do so far, for any given scenario, a good match between a required transfer 'predicted' by a 3d characterisation and the 'real' value estimated from a simulation only occurs when the 'effective plant margin' of the scenario is close to that assumed in the construction of the characterisation. In other words, the result is sensitive to 'effective plant margin'[6] meaning that it is likely that at least this should be included as a 4^{th} dimension in the characterisation. Further work that might be undertaken to address this issue is discussed in the next section.

5.3 Discussion

Our experience to date is that the characterisations for approach 3 are good in that, for cases where average conventional generation unit sizes and availabilities in an area are similar to those assumed in the characterisation, the characterisation gives a good 'prediction' of the required transfer capability that would be identified from a full 'specific' simulation of the same scenario. However, it can be seen from Figure 11 to Figure 14 that the assumed conventional generation unit size and availability can have a significant influence on the required boundary capability that is 'predicted' by a characterisation[7]. It can also be seen from Figure 11 to Figure 14 that the required boundary capabilities for boundaries 1 to 7 are particularly sensitive to the assumptions. While we can speculate at this stage why that is, some further work is required to fully establish it. (Because the trends are consistent, we are confident that some reasonable explanation can be readily identified[8]).

[6] By 'effective plant margin' we mean a plant margin that takes account of the ratio of wind generation capacity to conventional capacity within the total, and the changing 'capacity contribution' in the delivery of a given single bus LOLP. A plot of 'effective plant margin' against, for example, wind penetration might be readily identified from a suitable set of simulations or other reliability assessments for a given single bus LOLP. Such a plot could be used to identify the total 'contributory' generation for a given ACS peak demand.

[7] The sensitivity cases were chosen to represent the range of average unit sizes and availabilities that might be seen on either side of any of the SYS boundaries in the published NGET scenarios. The validity of this range is reflected by the fact that the results of 'specific' simulations of the same scenarios generally lie within the range of the sensitivities. (The specific simulation results reflect the actual unit sizes and availabilities in an area in the scenario in question, and these do vary).

[8] For scenarios in which the majority of generation capacity in the north is wind generation, one possibility is that the direction of the required transfer has changed – for approach 1 the critical required capability is from north to south while for approach 3 under certain circumstance it might be from south to north.

We feel that the observed sensitivities to the assumed conventional generation availabilities and sizes are likely to be a reflection of underlying variability of conditions on the transmission system rather than of the characterisation approach *per se*. While the sensitivities do seem to be significant, it may be noted that approach 1(b) is subject to the same sensitivities in that, while the underlying assumptions have not been stated explicitly, they are implied in what is – in effect – a characterisation. On the other hand, approaches that might be less sensitive will depend on the provision of considerably greater volumes of detailed data.

In terms of how to manage the sensitivity of a characterisation to the assumed conventional generation sizes and availabilities, we feel that a pragmatic approach might be to recognise that the purpose of approach 3 is, in effect, to provide a 'backstop' whereby customers' reliability of supply is not unduly reduced[9]. As can be seen from Figure 8 and Figure 9, a reliability criterion leads to the highest required boundary capability only on certain boundaries; as one would expect, these are where there is a small generation capacity on the importing side relative to demand, and in these cases the individual conventional generating units happen to be relatively large. This in turn might permit the identification of a prudent 'least regret' assumption for the characterisation.

We have not so far identified a satisfactory characterisation of approach 4[10] though we do have some further options to try which may turn out to be suitable[11]. In addition, there are at least two established methods – independent components analysis (ICA) and artificial neural networks (ANN) – that, because of their characteristics as generalised interpolators, have very good prospects to achieve the required aim. Furthermore, we believe that they could be evaluated relatively quickly with no more than 3 months' work likely to be sufficient to get a good first indication.

In the absence of further work on ICA or an ANN, either of the following might be possible:

- a family of characterisations might be developed, each for a different 'effective plant margin' for example, with the transmission planner applying the one that matches most closely the future scenario (generation and demand 'background') being assessed; or
- the generation equal access rule is only applied if the scenario being assessed lies within a certain range (defined, for example, in terms of 'effective plant margin'); otherwise, either some generation must be regarded as 'non-contributory' or another rule – based on reliability or an explicit economic assessment – must be relied upon.

The second of the above, while – in our view – not ideal, could be developed more quickly than an approach based upon ICA, ANN or a family of characterisations.

[9] The basic purpose of approach 2 is the same, though it requires much more data and a more complex calculation.
[10] Neither have we compared the quality of the approach 4 characterisation with that inherent in approach 1(b).
[11] One promising idea involves use in the main characterisation axes of the average available generation capacity rather than total installed capacity.

6 Conclusions

We feel that the criteria underlying approaches 3 and 4 are essentially sound and either of them might be regarded by electricity supply industry stakeholders as providing a rational, clear and unambiguous basis for investment in transmission. However, in view of the requirement that any new MITS planning rule should not deliver less reliability of supply than that presently delivered, we feel that a suitable basis for a new MITS planning rule might be as follows:

> the required transmission capability, either N-1 or N-2 secure as appropriate, should be
>
> i. that determined for the satisfactory meeting of peak demand for electricity; or
> ii. that determined by the provision of equal access to the market for generation; or
> iii. that determined by an economic evaluation,
>
> whichever is the greatest.

The re-characterisation of approach 3 that we have recently undertaken seems to us, based on what we have been able to do so far, to be sufficiently good provided there is agreement on suitable assumptions for ‘typical’ conventional generation unit size and availability. Further work is required to develop a complete characterisation for approach 4, though results so far seem promising in that there would indeed appear to be smooth relationships in the problem space.

Options for further work on approach 4 include:

- application of independent components analysis;
- development of an artificial neural network;
- development of a family of 3d characterisations;
- specification of a validity rule that limits application of approach 4.

We feel reasonably confident that 3 man-months’ further work on the first two options would give good indications on their prospects for inclusion in a revised GB SQSS in the next 6-12 months.