Audit of the BID3 Pan European Market Model for National Grid

Final Report

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Summary

National Grid Electricity Transmission (NGET) has procured a new pan-European electricity market model from Pöyry, BID3, to assist in new requirements for the Integrated Transmission Planning and Regulation Project (ITPR) and Electricity Market Reform (EMR). These require two main distinct functions for the new software: an assessment of within-GB constraint costs; and an assessment of likely interconnector flows.

Currently, National Grid uses its own in-house spreadsheet-based ELSI1 for estimation of within-GB constraint costs and ELSI3 for assessment of interconnector flows. Following a tendering exercise, National Grid commissioned Pöyry to:

1. Develop its BID3 software to enable its use in modelling how the wholesale market within GB would form an initial dispatch of generation followed by re-dispatch to satisfy inter-zonal power transfer constraints the latter of which determines the constraint costs incurred by the System Operator in GB;
2. Undertake a benchmarking of this extended BID3 functionality against National Grid's existing ELSI1 tool;
3. Undertake a benchmarking against ELSI3 of BID3's modelling of the European wholesale market and the consequential interconnector flows; and
4. Carry out a backcast of BID3's modelling of Europe against historical market outturn.

Reports of National Grid's intended use of BID3 – the "Market Modelling" report co-written by National Grid and Pöyry – and of the benchmarking exercises undertaken by Pöyry were reviewed by the authors of this report and a list of questions was given to National Grid. The authors discussed these questions with National Grid and Pöyry during a one-day meeting on the 7th of September, 2016, after which National Grid wrote a plan of actions they intend to take

over the short and longer term. Revised versions of the Market Modelling and ELS1 benchmarking reports were received on September 13th and 23rd respectively and have also been reviewed.

As a result of our reviews, we conclude that:

1. There are no grave concerns about the design and implementation of BID3 that should prevent National Grid from using it immediately in their forthcoming work for the next Network Options Assessment (NOA);
2. National Grid have, broadly speaking, captured the main points that should be addressed in the short-term before releasing a report to stakeholders on model development and use, and longer-term activities to further test and improve the functionality of the BID3 model.

In our opinion, the treatment of hydro power, foreign markets, weather-dependent renewables and generator constraints are generally better in BID3 than in ELSI1 and ELSI3, and thus we believe it will be capable of generating more accurate and representative results. However, in respect of National Grid's planned further work we make some recommendations concerning wind modelling, GB backcasting, identification of boundary transfer limits and use of integer constraints in wholesale market modelling. We also make some recommendations in respect of the ongoing management of inputs to BID3 modelling and the public reporting of development of BID3 and its use.

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1 Background and motivation

National Grid Electricity Transmission (NGET) has procured a new pan-European electricity market model from Pöyry, BID3, to assist in new requirements for the Integrated Transmission Planning and Regulation Project (ITPR) and Electricity Market Reform (EMR). These require two main distinct functions for the new software: an assessment of within-GB constraint costs; and an assessment of likely interconnector flows

We understand that the new software is expected to inform a number of new outputs that National Grid must deliver as part of its enhanced System Operator role:

- Forecast flows of existing and potential interconnectors to inform annual Future Energy Scenarios (FES);
- Annual publication of the "optimum level of interconnection" for the GB market from 2016/17 onwards;
- Welfare benefit assessments for interconnector projects under the 'Cap and Floor' regime;
- Ancillary services Impact Assessment, including constraint costs, for Interconnector projects under the 'Cap and Floor' regime;
- Cost benefit assessments to underpin a Connection Infrastructure Option Note (CION) for new interconnectors;
- Market modelling and cost benefit assessment to inform the development of the North Sea;
- Regional Group Investment Plan and Pan European Ten Year Network Development Plan.

National Grid is also obliged to undertake independent cost benefit assessments of network reinforcement options as part of the 'Needs Cases for Strategic Wider Works' submissions to Ofgem led by different transmission owners and on a GB-wide basis as part of a new licence obligation regarding production of the Network Options Assessment (NOA).

Finally, National Grid has existing obligations under Electricity Market Reform (EMR) to undertake short-term analysis and reporting to DECC on de-rating factor of interconnectors and forecast flows of interconnectors at different levels of GB capacity margin.

Until now National Grid has used its own spreadsheet-based tools developed in-house: ELSI1 for estimation of within-GB constraint costs and ELSI3 for assessment of interconnector flows. Following a tendering exercise, National Grid commissioned Pöyry to:

1. Develop its BID3 software to enable its use in modelling how the wholesale market within GB would form an initial dispatch of generation followed by re-dispatch to satisfy inter-zonal power transfer constraints the latter of which determines the constraint costs incurred by the System Operator in GB;
2. Undertake a benchmarking of this extended BID3 functionality against National Grid's existing ELSI1 tool (a GB focused dispatch model with internal boundary constraints);

3. Undertake a benchmarking of BID3's modelling of the European wholesale market and the consequential interconnector flows against ELSI3 (a north-west European dispatch model without sub-national internal network constraints); and
4. Carry out a backcast of BID3's modelling of Europe against historical market outturn.

We were engaged by National Grid in August 2016 to:

- Review the benchmarking reports produced by Pöyry which compare the performance of the BID3 model to National Grid's existing tools, ELSI1 and ELSI3;
- Review the market modelling report produced by National Grid detailing the BID3 model enhancements, data set-up and parameter configuration;
- Question Pöyry and National Grid representatives on the exercises undertaken, the assumptions made, model parameter configuration adopted, results derived and the analysis conclusions reached; with a focus on the modelling of balancing mechanism re-dispatch and how changes may impact the outputs and their relative materiality;
- Assist National Grid in determining whether it is necessary to undertake a further back cast of model performance to historic balancing market outturn or whether the evidence submitted is sufficient to provide assurance on the model setup;
- Prepare a short report outlining our conclusions on the robustness of the exercise, the suitability of National Grid's set-up, and the conclusions they draw.

The authors reviewed reports of Pöyry's two benchmarking exercises and of National Grid's intended use of BID3 – the "Market Modelling" report co-written by National Grid and Pöyry. A total of 237 questions and comments were provided by the authors; National Grid and Pöyry provided written responses to 171 of these.[1]

The authors discussed these questions with National Grid and Pöyry during a one-day meeting on the 7th of September, 2016, after which National Grid wrote a plan of actions they intend to take over the short and longer term. This plan of action and revised versions of the Market Modelling and ELSI1 benchmarking reports were received on September 13th and 23rd respectively and have been reviewed.

From reviewing the revised reports from National Grid we conclude that their short-term actions have been implemented, primarily giving more detailed or clearer descriptions and augmenting the results to look at particular differences between the models. We have provided National Grid with further comments on the revised reports received on September 13th and 23rd.

The long-term actions they identified can be summarised as follows (in order of the priority attributed to them by National Grid):

- Backcast model performance to historical balancing mechanism costs for constraints (High)

[1] The unanswered points were either self-evident (spelling and grammar) or multiple comments from the authors with a single response.

- Test plant dynamic constraints, ramp rates, minimum down time and mixed integer optimisation etc. (High)
- Test the influence of reserve constraints on the model and limits on non-synchronous generation – examining how BID3 can be used to provide future 'operational time frame' market signals (Medium)
- Test the scarcity rent function (High)
- Explore more sophisticated boundary outage modelling (Medium)
- Examine the inclusion of Power Transfer Distribution Factors (PTDFs) on interconnector capacities (Medium)
- Examine demand, wind and solar profiles to select representative years, considering overall output levels and correlation between European countries (Low)
- Explore enhancements in the modelling of renewables (wind turbine versus wind farm power curves, and diversifying solar panel orientations) (Low)

2 Differences between BID3's and ELSI's functionality

We understand that one of National Grid's motivations for seeking a new tool was to have access to enhanced functionality. The main enhancements that BID3 seems to offer compared to ELSI are:

- the ability to define bid and offer prices for system balancing separately from the estimated short-run marginal costs for each generation unit;
- the ability to locate individual generators and demand within pre-defined price areas and choose whether to constrain the wholesale market dispatch by net transfer capacities defined for interconnections between price areas;
- the ability to define 'scarcity rent' added to generator prices under stressed system conditions;
- the ability to model availability of wind and solar power with greater spatial granularity and consistent underlying meteorology;[2]
- a sophisticated model of how hydro power – run-of-river, reservoir-based and pumped storage – would be dispatched;
- the ability to constrain a wholesale market dispatch by generator ramp rates and minimum on and off times and to model start-up costs explicitly using integer constraints;
- a representation of the effects of an interconnector owner's opportunity cost, the cost of remote generation and the effect of network losses on the cost of SO to SO actions when changing the flows on interconnectors into or out of GB;

[2] In particular, BID3 uses annual profiles for wind and solar generation that are based on specific weather years, whereas ELSI works by sampling individual days from across several years and stiches those together to create an annual profile.

- the possibility of defining many more within-GB zones and transmission network boundaries than had been modelled in ELSI;
- the ability to model within-year variations in fuel costs;
- the ability to define average availability for different generators on a monthly rather than seasonal basis;
- access to more representative data from Pöyry's market intelligence to quantify a number of parameters that National Grid had itself not previously articulated (particularly relating to the power system outside of Britain).

Furthermore, ELSI's ability to represent within-year variations in boundary transfer capability has been retained, e.g. due to the scheduling of maintenance outages, and relevant boundary transfer limits can be defined for each direction and for future years to reflect, where appropriate, enhancements due to network reinforcement.

We understand that BID3 also offers some options for estimation of network losses and an 'auto-build module' which enables optimal interconnector build between markets to be estimated.

Aside from how network losses can influence the cost of actions in GB to reduce or increase interconnector flows, the above two features were not discussed in the reports we received. As a consequence, we do not comment on them below.

3 Methodology for benchmarking BID3 against ELSI

Given the opportunity to make use of new data and to define zones in new ways, two tests of BID3 are appropriate:

1. a demonstration of the effect of the enhanced functionality of BID3 relative to ELSI;
2. an exploration of the effect of use of new data and system representations.

The first of these tests should, as far as possible, use exactly the same input data and system definitions as ELSI to enable confidence that differences in results between BID3 and ELSI are due solely to the different ways in which BID3 calculates the dispatch and re-dispatch. The second of these tests would then reveal the compound effects of both modelling technique and data inputs.

In order to demonstrate the use of BID3 compared with ELSI, Pöyry has provided National Grid with two "benchmark reports":

1. a comparison with ELSI1 for quantification of within-GB annual constraint costs;
2. a comparison with ELSI3 for estimation of likely interconnector transfers into or out of GB.

In addition, the latter benchmarking report describes a 'backcasting' exercise that Pöyry produced for a previous client which aimed to broadly reproduce historic European wholesale market and interconnector behaviour.

The first report (ELSI1) follows the appropriate two-stage approach. This allowed the authors to conclude that ELSI1 appears to be replicated well when BID3 is set to match all inputs. Some notable differences were observed (up to 6% on certain boundary flows), and, via National Grid, Pöyry provided further information on these after the Q&A session. We have provided National Grid with our responses to this further information.

The second (ELSI3) contains a single comparison of BID3 using Pöyry inputs compared to ELSI3 using National Grid's inputs. This made the job of identifying, diagnosing and understanding the differences between the two tools more difficult, but was defended on the grounds of cost efficiency due to the additional work required to align all the input data in the two models. We believe this prioritisation of resources was reasonable, as the exercise with the clearest delineation between the effects of data and of methodology (the benchmarking of ELSI1) covers the functions that are most central to National Grid's intended usage of the BID3 model.

The backcast of BID3 against historic European market outturn was broadly useful, except for the fact it excluded Ireland and Norway, which are or will soon be important neighbours to the GB electrical system. Pöyry explained that the exclusion of these countries was in part due to the requirements of the previous customer who commissioned the backcasting, but was also because, in Pöyry's opinion, their markets cannot be properly represented by any price-based model. For example, the Single Electricity Market on the island of Ireland is not dispatched entirely on a price basis due primarily to severe internal congestion over the North-South interconnection.

4 Reports on the development and use of BID3

Our understanding is that National Grid will publish versions of some of the three reports that we have reviewed. We provided National Grid with 284 detailed comments on both the original and revised versions of those reports. These concerned, for example, the evidence presented in respect of the benchmarking exercises and descriptions of the modelling algorithms.

Within the final, published versions of these reports, we recommend that National Grid and Pöyry focus on the clarity of language and consistent use of well-defined terminology to avoid any confusion. A motivation for the public reports is to give stakeholders confidence in the new modelling process, so a focus should be placed on explaining not only what the aims are, how they were met before and what differences there are between the former and new modelling approaches, but also *why* there are differences between the models' results.

In addition, the different uses of BID3 should be made clear:

- GB wholesale market modelling and costing of re-dispatches in the Balancing Mechanism (as was previously done in ELSI1);

- European wholesale market modelling and the consequential estimation of likely international interconnector flows (as was previously done in ELSI3).

5 Management of inputs to BID3

National Grid has an established set of inputs to ELSI. In addition, through the contract with Pöyry, National Grid has gained access to other data for use in BID3 derived from Pöyry's own market intelligence. These inputs mainly pertain to the costs and constraints of individual generators, in particular those on the continent of Europe, and the availability of power from weather-dependent renewable generation, i.e. hydro, wind and solar. In its use of BID3 to date, National Grid's own analysis has been relied on for definition of availabilities of schedulable generation in Britain, demands at each location within GB at each period within a year and within-GB boundary transfer capabilities, including how they vary in different seasons and are changed when planned network outages are taken.

It will clearly be important that inputs and assumptions are kept under review and updated when appropriate. It is our understanding that National Grid will establish a new European modelling team to develop and manage inputs to National Grid's use of BID3 for modelling of the European power system.

We would encourage National Grid to pay particular attention in its ongoing use of BID3 to:

1. the modelling of wind and solar power;
2. ensuring consistency and accuracy in boundary modelling.

With respect to wind modelling, although annual average capacity factors would have varied significantly over the last 30 years due to prevailing weather conditions, the modelling of 30 years would represent a significant computational burden. If less than the full 30 weather years is to be used, we recommend that National Grid carefully identifies a set of representative years. Ideally, the chosen representative years should capture the range of annual capacity factors (e.g. the P10, P30, P50, P70 and P90 across the 30 years[3]), and would also exemplify the range of cross-continent correlations or, least, some 'central' values. When used in BID3, these would allow the influence of wind performance on, for example, constraint costs to be estimated.

When undertaking wind power synthesis, we recommend that care is taken over the choice of wind speed to power conversion curve and that this choice is justified. Pöyry's decision to use the power curve for an individual turbine as opposed to an aggregate 'farm curve' does not follow the best practice employed by Ofgem or in academic research.[4] This curve should be smoothed to represent the one or more farms that may be present in a particular 20km × 20km (400km^2) area represented by the wind resource data. The use of a single turbine curve will

[3] It may be noted that historical outturns are only available for a limited number of years in Britain, and fewer years in other countries, so there may therefore be some dependency on synthesis of available wind power using historical wind speeds from weather models (such as reanalyses).

[4] For examples, see Ofgem, 2012: *Electricity Capacity Assessment* (report 126/12); I. Staffell, 2014: *Renewable Energy* 66 775–786; G.B. Andresen, 2015: *Energy* 93 1074–1088; G.S. Hawker, 2016: *PSCC 19*, Genoa.

likely over-represent the volatility of wind output, and thus the frequency of very high or very low capacity factors, and will be especially important for offshore zones during periods of high wind speed, due to the dramatic cut-off of the turbine power curve which becomes diversified in the aggregated farm curve.[5]

If National Grid foresees that the representation of solar power will be important for some outputs (e.g. due to its influence on future minimum net demand), then we recommend investigating more realistic representations of the installed solar fleet than used in the present implementation of BID3. Incorporating the known diversity in panel orientations[6] will lead to systematic differences in the profile of solar output, reducing it at midday and increasing it during early morning and in evening hours.

We recommend that, in respect of more sophisticated boundary modelling, the process by which nominal intact and 'prior outage' secure boundary transfer capabilities are determined is (a) consistent with what is done for the Electricity Ten Year Statement, (b) checked for consistency and appropriateness with respect to similar processes used for determination of net transfer capacities (NTCs) on the continent of Europe, (c) undertaken in each direction for each boundary that might credibly see transfers in either direction at some time in the course of a year of operation and (d) documented clearly. Noting that some boundaries have been subject to a lot of construction work in recent years that is unlikely to be sustained indefinitely, the number of days for which each boundary is subject to planned outages should be kept under review.

One point about modelling of the dispatch of generation that we did not find addressed in the reports we reviewed concerned the scheduling of reserve. Ordinarily, a particular total amount of 'headroom'[7] can be expected on synchronised generating plant in order to cover the loss of the single largest infeed. The need for a particular amount of 'frequency containment reserve' (FCR) – normally referred to in Britain as 'frequency response' – and limits to how much can be provided by any one generating unit would influence the sharing of 'headroom' between different units. Further 'headroom' would, in general, add to 'frequency restoration reserve' (FRR, broadly equivalent to short-term operating reserve in Britain) though fast starting generation and demand reduction can also contribute to FRR. The location of 'headroom' would change both the initial boundary transfers and the generators from which offers might be accepted and, as a consequence, can have an influence on total constraint costs. Furthermore, it is our understanding that participants in the GB wholesale market often schedule their own 'headroom' rather than it only being 'bought' by the System Operator through ancillary service markets. In addition, the future connection and operation of larger single generating units than are seen on the GB system now and increased penetration of wind power would change the required minimum volumes of FCR and FRR respectively. We would recommend that National

[5] If average speed within the 400km^2 area rises above 25 m/s, the current method assumes that all turbines in that area shut down simultaneously. In reality, the speed experienced at specific turbines in this area will be a distribution centred around 25 m/s, and so some would have already shut down, some will not.

[6] For examples, see J. Leloux, 2015: *EU PVSEC 31*, Hamburg; S.J. Pfenninger, 2016: *Energy* 114 1251–1265.

[7] 'Headroom' is the difference between the initial operating point of a generator and its maximum output.

Grid assesses the impact of modelling of reserve on the estimation of annual constraint costs and adopts some appropriate rules of thumb for use in BID3.

Finally, we recommend that clarity is given with respect to the meaning, derivation and use of generator availabilities in National Grid's future use of BID3, analysis supporting the Capacity Market and the Summer and Winter Outlook reports. In particular, both planned and unplanned availabilities should be clearly stated with seasonal variations noted where appropriate. Sources of data and any pre-processing steps should also be noted.

Overall, while noting the above recommendations for development and management of data, our opinion is that the existing set of BID3 inputs generally represents a reasonable starting point in respect of immediate use of BID3 by National Grid.

6 Next Steps

In addition to our recommendations above in respect of management of data and publication of reports, we recommend that National Grid:

1. performs an additional backcasting exercise relating to estimation of within-GB constraint costs;
2. explores the use of BID3's capability to use mixed-integer linear programming (MILP) in the determination of initial generator dispatches that respect minimum stable generation and take explicit account of generator start-up costs.

We recommend that a backcasting exercise is undertaken to compare use of BID3 in estimating annual constraint costs with historical outturns. This is likely to help to build confidence in, and understanding of, National Grid's new modelling methodology. It may also shed light on differences in results between ELSI1 and BID3 that the contractors from Pöyry have been unable to explain.

The use of BID3's capability to use mixed-integer linear programming (MILP) in the determination of initial generator dispatches promises a more faithful reproduction of how generation owners would actually dispatch their plant in that it can capture such constraints as minimum stable generation and minimum on and off times. However, as well as requiring more data to represent these constraints, it has a significant penalty in terms of model run time.

In the discussions on the 7th of September, 2016, National Grid's representatives expressed the view that, relative to ELSI1, it would also be too big a jump to go straight from using ELSI (which uses a relatively simple linear programming based optimisation) to using BID3 with MILP. We agree that it is sensible in the near-term to gradually ease into the new model and stick with the simpler, linear programming (LP) based dispatching of generation: i.e. that users walk before they run. However, with time as confidence is gained in how the model performs and how wholesale dispatches are determined, we expect that there would be value in using the MILP functionality.

On the other hand, there is a valid question in respect of the value of using MILP when modelling the far future such as the end of an ETYS period or out to 2040 for Future Energy Scenarios (FES). The scale of uncertainty in inputs is far bigger than in the model's reproduction of how market participants would perform for a given 'macro-scenario' of generation, network and demand 'background'. Especially given the long run-time, it is likely to be better to be imprecise and give more scope for consideration of uncertainties in the 'macro-scenarios' rather than be very precise and wrong. Use of the LP approach may introduce some systematic inaccuracy, such as consistently under-representing the impact of wind on plant ramping and prices. With experience in using the tool, a comparison between the two modes may not only reveal which biases arise but also what corrections might be made to minimise their impact.

7 Conclusions

Based on the reports we have seen and the discussions we had with representatives of National Grid and Pöyry on September 7th, 2016 and what we understand from them regarding BID3's modelling capabilities, our overall judgement is that BID3 represents a useful step forward relative to ELSI.

We have made a number of recommendations in respect of the reporting of BID3 and its differences from ELSI, and the management of data. These concern:

- the need to be clear not just about how BID3 will be used and the differences in its results from ELSI but also why those differences arise;
- the availability of power from wind and solar;
- clarity on where values used for the availability of 'schedulable' generation come from;
- clarity on how boundary transfer capabilities are defined.

We also recommend that National Grid:

1. performs an additional backcasting exercise relating to estimation of within-GB constraint costs;
2. reviews the extent to which modelling of reserve influences the estimation of constraint costs;
3. explores the use of BID3's capability to use mixed-integer linear programming (MILP) in the determination of initial generator dispatches that respect minimum stable generation and take explicit account of generator start-up costs.

The backcasting of within-GB constraint costs should help to shed light on the relative importance of improved modelling of the availability of power from wind and solar, the modelling of reserve and the use of MILP in forming initial dispatches. However, we believe that improvements should be readily realisable in respect of modelling of wind and solar in advance of that exercise being started.

Overall, while noting the above recommendations for development and management of data, our opinion is that the existing set of BID3 inputs generally represents a reasonable starting point in respect of immediate use of BID3 by National Grid.