Electricity System Restoration Assurance – 2023 Report

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1 Introduction

In 2021, the authors of this report were engaged by National Grid Electricity System Operator (NGESO) to provide an audit of a model developed by NGESO to assess the time that would be taken to restore electricity supplies on the power system in Great Britain (GB) in the event of a GB-wide power outage, henceforth referred to as the Model. The resulting "Electricity System Restoration Assurance – Model Audit" was submitted to NGESO on February 10, 2022. It contained some key findings and recommendations for the further development and use of the Model. The report was also shared with OFGEM.

NGESO has taken a number of actions related to the recommendations since the February 2022 audit and report.

The objectives of this new report now are:

- To review the progress and the priority setting of the work undertaken, in progress and planned on restoration modelling as a response to our recommendations plus some model change requests from within NGESO.
- To comment on Model results for NGESO assessment of 2023 Black Start Restoration Performance.

This report is based on the following documents:

- The "Electricity System Restoration Assurance – Model Audit" from February 10, 2022.
- The presentation "Model Audit – Findings and Recommendations" from February 15, 2022, authored by Simon Waters, NGESO.
- The document "Summary Briefing – 2023 Black Start Restoration Performance" from November 11, 2022, authored by Simon Waters, NGESO.
- A short report "Restoration Modelling Activities since February 2022" provided by Simon Waters, NGESO.

2 Review of Model updates

In order of priority and urgency, our key recommendations from the February 2022 Model Audit are:

1. Clarify the interpretation of ESRS (Electricity System Restoration Standard) targets.
2. Implement a formal process to agree on Model input data.
3. Perform systematic sensitivity analysis with respect to input data.
4. Improve Model documentation.
5. Improve the modelling of demand and distributed generation.
6. Prepare for restoration strategy updates and bold changes to strategy.
7. Revisit the software technology.

As a response to that NGESO has developed a priority order for the individual work items as shown in Table 1. The additional change request from inside NGESO is shown in Table 2. Both tables are copied from the document "Restoration Modelling Activities since February 2022".

Table 1: Key Work Areas from the Audit report

Audit Recommendation	Modelling Development	Estimated resource	Risk(s)	Priority	Delivery
1	Establish Standard confidence level(s) with BEIS	1 or 2 month - through regular BEIS meetings?	Low, the model functionality already exists	1	29th July 2022
2	Data verification process for any new assumptions/data	1 month - some data available through BSTG work	Low	5	29th February 2024
3	Systematic sensitivity analysis	2 or 3 months to undertake systematic analysis of all major assumptions	Low or medium	2	28th October 2022
4	Model documentation - technical specification	3 months?	Low	6	26th July 2024
5	Embedded demand and generation improvements	6 to 8 months (if data available?)	med or high	3	28th July 2023
6	Future proofing model - new developments such as DER/Skeleton networks, offshore wind, contract changes etc.	1 month annual update, strategic changes (DER etc) significant time required.	Annual process low risk, new developments medium risk	4	22nd December 2023
7	Review software platform evaluate risk/benefit of alternatives	Estimate 6 - 12 months, delivery unknown 2 years?	High or very high	7	End November 2025
	Totals	***23 to 63 months***	***2 to 5 years effort***		

Table 2: Additional Work Areas from inside NGESO

ESO Modelling Development	Estimated resource	Risk(s)	Priority	Delivery
Align 6 x BS zones to DNO licence areas*	3 or 4 months rebuild	Medium	2	Mid 2023

2.1 General remarks on NGESO's action list

We understand that the column "Risk(s)" refers to the difficulty of implementation (or vice versa of not being able to accomplish the job in due time) and we fully understand the priority setting according to "low hanging fruits first". However, from a business perspective we recommend a different approach for risk evaluation focussing on the risk for NGESO and for use of the Model in guiding restoration strategy and procurement of restoration services of NOT solving these work items with the possible consequence that NGESO might not be able to meet UK Government requirements and comply with the restoration standard. From that business perspective high risk work items should have the highest priorities, regardless of how difficult their implementation is.

2.2 Item 1 – Confidence levels

NGESO states that restoration expectations written into the ESO Licence are based on average values – in terms of assessment of stochastic processes, "expected" values – and that a consensus was reached that these remain the basis on which they report results. This is not unreasonable.

- As with assessment of the outcomes of all stochastic processes, i.e. those subject to uncertainty, it is very difficult to assess outcomes at the "tails" of probability distributions both accurately (the estimated values are close to the true values – this is difficult to achieve due to the challenge of modelling reality very closely) and with high precision (the estimate of the statistic of interest produced from the particular set of trials of the Monte Carlo process is close to the result that would come from an infinite set of trials). For example, in a Monte Carlo simulation such as used in the Model, the calculation of P90 values for restoration times, i.e. those that would be exceeded in only 10% of cases, with a certain degree of precision would take a very large number of trials of the simulation, i.e. would be computationally expensive.

- The modelling details are probably not close enough to real world behaviour when it comes to rare events and combinations of circumstances that would lead to very long restoration times. This includes aspects of demand modelling, the loss of auxiliary supplies in substations, the modelling of the re-synchronisation of islands and the active power support between regions. Therefore, with the given modelling approach, P90 values would probably be highly inaccurate.

- A statutory requirement to restore 60% of load in 24 hours and 100% in 5 days with 90% confidence is likely to result in need for very large additional investments compared with a standard based median or average restoration times, with decisions made on possibly inaccurate calculation results.

However, we recommend that this decision, the implications for modelling and the resulting consequences for risks faced by energy users are clearly explained in reporting and in discussions with OFGEM and Government. This includes two aspects:

- The fact that the reporting is based on average values representing probability distributions with significantly high standard deviations. Senior policy makers should be made aware that, if the reported average value meets the set target, the standard might be missed in half of all scenarios with the potential for a large number of scenarios to result in restoration time significantly longer than 24 hours for 60% of demand in every region or 5 days for all GB demand.

- The reported average values have an error band related to the limited number of Monte-Carlo simulation trials and inaccuracy resulting from any model deficiencies[1]. Whereas the latter are hard to quantify, the former can be quantified by statistical means using some reasonable assumptions. As a result, a confidence interval can be calculated saying that with a probability of, say 95%, the true value (within the capability of the Model to model things accurately) of the average value is between X as the lower and Y as the upper limit.

2.3 Item 2 – Data verification process

We understand that, since our February 2022 Audit report, a considerable effort has been spent to update the database of the Model. This includes a review of data of all generation units represented in the Model.

To keep the database of the Model up-to-data is a necessary task that should be undertaken on a regular basis and we understand that the approach taken – where stakeholders have been asked for

[1] With respect to modelling of any stochastic process, there are, in general, two main sources of uncertainty: ‘aleatory’ uncertainty relating to fundamental uncertainty of the process being assessed and the outcome of any particular event – in this case, the conditions under which a system collapse occurs and the time it takes to restore supply – being impossible to predict in advance with a very high degree of confidence; and ‘epistemic’ uncertainty relating the modeller’s ‘state of knowledge’ and the fact that it is impossible to model the process completely accurately. Little can be done about the former, i.e. the stochastic nature of the real-world process, but the extent of uncertainty relating to the latter can be reduced through investment in model development, data collection and model calibration and validation. Moreover, there is also uncertainty associated with a Monte Carlo estimation process, i.e. the way in which values are sampled and how many trials of the estimation process are done. A good model-based estimation process should report not just, for example, median or average outcomes but also the extent of uncertainty in model results.

updates to data where the NGESO modeller has reason to believe that the value might have changed – is a pragmatic and quick but still not systematic solution. Given the importance of the accuracy of the database, we still recommend to establish a formal process involving all "data owners" as was recommended in our Audit Report. This would guarantee proper documentation plus timely and accurate responses from data providers.

2.4 Item 3 – Systematic sensitivity analysis

We understand that our recommendations have been followed for some sensitivity studies related to the switching capability and time for Distribution Network Operators (DNOs) to provide block loads and to DNO network control functions' resilience. In contradiction to the target set in Table 1, a wider suite of studies has not been performed yet.

We strongly recommend this wider set of sensitivity analyses, but agree that it should be based on the latest version of the Model and hence is postponed until this version is available, in particular the completion of the DNO zonal model. This analysis will be useful to help identify key pinch-points and also focus the data acquisition process on topics of high impact.

2.5 Item 4 – Model technical specification

We understand that this work item has not yet been started due to lack of resources.

2.6 Item 5 – Embedded demand and generation improvements

We understand that work has been started to better represent embedded generation at DNO level. The embedded generation sources will be separated into wind, solar and other categories for each zone and an aggregated characteristic for each category in each zone shall be developed to prevent overloading the Model. This will also allow to distinguish TGSD (Total Grid System Demand, i.e. the demand as seen from the transmission network) from total GB demand.

We support the general approach. However, in our opinion it would be useful to distinguish further between embedded generation resources that are or are not controllable from the DNO control room[2]. We assume that, while it of course cannot be guaranteed that power will always be fully available from them, all RES (Renewable Energy Sources) connected to the transmission network are fully controllable from the NGESO control room. Similar to Item 2 above, the sources of data should be verified and the data acquisition should be included into the formal process.

2.7 Item 6 – Future proofing for new developments

We want to pinpoint again that, in our understanding, "new developments" may include many more aspects besides the representation of services from smaller distributed energy resources (DER). The Model should be capable of aligning to any foreseeable strategy changes as e.g. the introduction of a skeleton network approach.

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[2] By virtue simply of whether the point of connection has been connected to an energised section of network, a DNO will have some degree of control on the infeed of any generator into that section of network. However, for many small scale generators, the DNO has no control over the level of infeed. In a restoration process in areas with very high penetrations of, for example, rooftop solar PV, this leads to uncertainty in the power flows seen within the distribution network and the transfer of power between distribution and transmission. In a worst case, it might be that a request from the ESO to a DNO to restore a demand block of a certain size results in a net flow of power from distribution to transmission. A similar problem of uncertainty also arises in respect of reconnection of loads, in particular large loads such as heat pumps and electric vehicle chargers.

2.8 Item 7 – Review of IT platform and dependencies

We understand the difficulties of this work item given the lack of resources. However, we still believe that not migrating the Model to a more easily maintainable software platform constitutes a high long-term risk from business and licence compliance perspectives.

2.9 ESO Modelling requirement for DNO boundaries

In our view, aligning the black-start zonal boundaries with the latest DNO boundaries is a necessary task for the given restoration strategy. Therefore we support this work item. Note that this might be different for other restoration strategies. For example, a skeleton network strategy does not need to comply with DNO boundaries, but it still must be known which DNO is connected to the individual substations of the skeleton network.

3 Comments on the 2023 Restoration Performance Statement

As a basis for commenting on the 2023 Restoration Performance Statement we only have the "Summary Briefing" document available, which gives little insight into the details of changes in the database and Model as such. Therefore, a comprehensive review of the results is not possible. Instead following few observations are given.

- Footnote 1: "Not limiting the study to winter months" may result in more favourable restoration times compared to previous reports, which were focused on the winter season only. This is due to the seasonal variations in demand, which is probably lower in the other three seasons. However, it might also be noted that a potentially significant fraction of both generation and network capacity may be unavailable outside the winter season due to either maintenance or construction outages.

- Figure 1: We are curious about the large changes in restoration times from 2021 to 2022 and 2023. Having in mind that the preliminary sensitivity analysis on DNO switching times has shown their high impact, we wonder whether – as asserted in the summary of the 2023 modelling – changes in black start unit (BSU) services result in such big variations. A careful analysis of the impact of BSU services on the overall restoration performance should be done to verify the results.

- Figure 3: Given the high regional differences in the time to restore 100% of demand, modelling of the support given between regions should be revisited. In particular, for the south east (SE) region, where demand restoration depends on support from other regions, restoration priorities between regions may have a huge impact. Also, regional restoration times are highly dependent on the times at which or conditions under which the individual islands are synchronized back to the NETS (National Electricity Transmission System) allowing bulk power transmission over long distances. We recommend to crosscheck whether the Model is appropriate in that respect.

- For the presentation of results we strongly recommend the inclusion of a more detailed explanation of the probabilistic nature of the process, see our comments in section 2.2.

4 Conclusions and recommendations

With the limitations of the resources made available to it, the approach taken to compile the "2023 Restoration Performance Statement" appears fair and reasonable. We recommend a closer look at the reasons for the changes in results of years 2021, 2022 and 2023.

Regarding the long-term perspective, we recommend a review of setting of priorities among the Model maintenance, documentation and development work items and, accordingly, an adjustment of the resources made available.

Appendix: Terms and definitions

BEIS	Department for Business, Energy and Industrial Strategy
DNO	Distribution Network Operator
ESO	Electricity System Operator
ESRS	Electricity System Restoration Standard
NETS	National Electricity Transmission System
NGESO	National Grid Electricity System Operator Limited
OFGEM	Office of Gas and Electricity Markets; Great Britain's independent energy regulator
RES	Renewable Energy Sources
TGSD	Total Grid System Demand