NOMs Methodology
Issue 18

VERSION CONTROL

VERSION HISTORY

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28/03/18	1	Draft
16/04/18	2	Amended Draft
27/04/2018	3	Submitted
14/05/2018	4	Feedback
06/05/2018	5	Review
14/06/2018	6	Final Submission

CONTENTS

1. PURPOSE AND SCOPE

Britain's electricity transmission network transmits high-voltage electricity from where it is produced to where it is needed throughout the country. It broadly comprises circuits operating at 400, 275 and 132kV, owned and maintained by three transmission companies:

- National Grid Electricity Transmission plc (NGET) for England and Wales
  - Over 14,000 km of overhead line and 600 km of underground transmission cable routes interconnecting over 300 substations.
- Scottish Power Transmission Limited (SPT)for southern Scotland
  - 4,000 circuit km of overhead line and cable interconnecting 137 substations
- Scottish Hydro Electric Transmission plc (SHE-T) for northern Scotland and the Scottish islands groups.
  - Over 5,100 circuit km of overhead line and cable interconnecting 138 substations

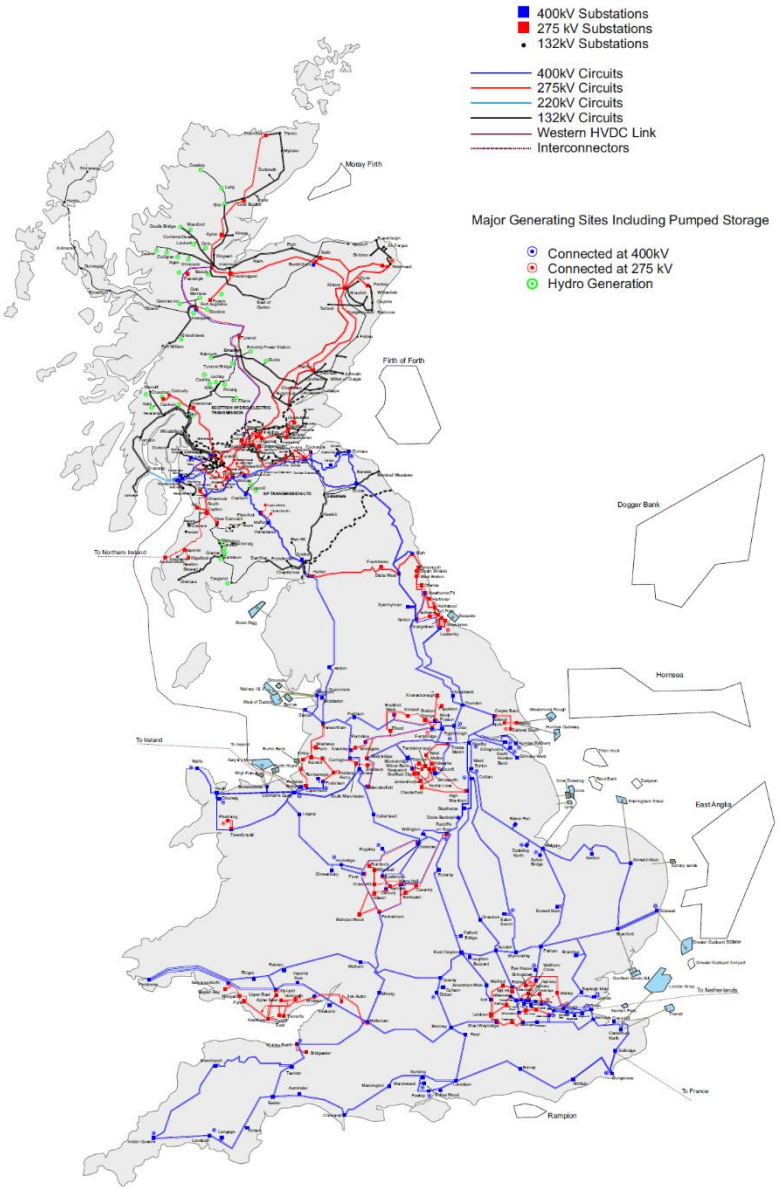

Figure 1

Each Transmission Owner has several assets which are used to create the overall transmission network. These Lead assets can be grouped together based on their function, as shown below;

- Substation Assets - Used to increase or decrease voltage/current to regulate transmitted power
    - Transformers
    - Reactors
    - Circuit Breakers
- Circuit Assets - Assets which are used to transmit power across a distance via a circuit
    - Cables
        - Solid
        - Underground
        - Subsea
    - Overhead Lines
        - Steel Tower
        - Conductors
        - Fittings
    - Poles

Each lead asset is further described in the Network Asset Risk Annex.

The RIIO (Revenue = Incentives + Innovation + Outputs) regulatory framework places emphasis on incentives and outputs to drive the innovation that is needed to deliver a sustainable energy network to consumers.

Outputs are a fundamental element of the RIIO framework. Primary outputs, (Safety, Reliability and Availability, Environmental Impact, Connections, Customer Satisfaction and Social Obligations) monitor each onshore Transmission Owner's (TO) performance for the delivery of end services to consumers. The Network Output Measures (NOMs) are binding secondary outputs which show that the TOs are providing consumers with long-term value for money through a set of early warning measures or lead indicators. These assess the underlying performance of the transmission system.

The NOMs are designed to demonstrate that the TOs are targeting investment in the right areas to manage network risk effectively, ensuring that the TO will continue to deliver primary outputs and a network that is fit for purpose in the future.

As network investment takes place over the longer term, there would be a time lag before any under-investment in the assets would impact the primary outputs. For example, if an asset is not replaced when required, it may be some time until the asset fails and impacts network reliability. Using the NOMs, the Licensees can identify the work needed to manage their assets to deliver a known level of network risk and hence provide assurance that they will maintain performance in future price control periods.

For the price control period (RIIO-T1) which covers the eight years from 1 April 2013 to 31 March 2021, Special Licence Condition 2L sets out the requirements for the NOMs for each of the TOs.

Special Licence Condition 2L requires that each licensee must at all times have in place and maintain a methodology for Network Output Measures ("the NOMs methodology") that:

a. facilitates the achievement of the NOMs methodology objectives;

b. enables the objective evaluation of the NOMs;

c. is implemented by the licensee to provide information (whether historic, current, or forward looking) about the NOMs. This may be supported by such relevant other data and examples of network modelling as specified in any Regulatory Instructions and Guidance (RIGs) issued by the

Authority in accordance with the provisions of Standard Licence Condition B15 of the Transmission Licence for the purpose of this condition; and

d. can be modified in accordance with specific provisions.

The NOMs Methodology Objectives are:

a. the monitoring of the licensee's performance in relation to the development, maintenance and operation of an efficient, co-ordinated and economical system of electricity transmission;

b. the assessment of historical and forecast network expenditure on the licensee's Transmission System;

c. the comparative analysis of performance over time between GB Transmission and Distribution Systems and with international Transmission Systems;

d. the communication of relevant information about the licensee's Transmission System to the Authority and other interested parties in an accessible and transparent manner; and

e. the assessment of customer satisfaction derived from the services provided by the licensee as part of its Transmission business.

The NOMs methodology is designed to enable the evaluation of:

a. the **Network Asset Condition measure**, which relates to the current condition of the network assets, the reliability of the network assets, and the predicted rate of degradation in the condition of the network assets, which is relevant to assessing the present and future ability of the network assets to perform their function;

b. **t**he **Network Risk measure**, which relates to the overall level of risk to the reliability of the licensee's Transmission System that results from the condition of the network assets and the interdependence between the network assets;

c. the **Network Performance measure**, which relates to those aspects of the technical performance of the licensee's Transmission System that have a direct impact on the reliability and cost of services provided by the licensee as part of its Transmission business;

d. the **Network Capability measure**, which relates to the level of the capability and utilisation of the licensee's Transmission system at entry and exit points and to other network capability and utilisation factors; and

e. the **Network Replacement Outputs**, which are used to measure the licensee's asset management performance as required in Special Licence Condition 2M (Specification of Network Replacement Outputs).

The methodology is designed to enable the evaluation of all five NOMs. Each measure is reported to the Authority annually to facilitate the ongoing assessment of each TO's performance, through the regulatory reporting process.

1.1. ONGOING REVIEW & DEVELOPMENT OF THE NETWORK OUTPUT MEASURES

Part E of Special Licence Condition 2L requires that each licensee must, from time to time, and at least once every year, review the NOMs methodology to ensure that it facilitates the achievement of the Methodology Objectives.

The methodology is jointly reviewed by all TOs. The TOs regularly discuss the methodology as well as the development of the NOMs. The terms of reference for these review meetings are:

- the TOs will meet to discuss the appropriateness of the current NOMs in meeting the requirements of Special Licence Condition 2L;
- share information to ensure consistency and calibration across the TOs; and
- discuss and resolve common issues with the implementation of NOMs

Outside of the annual review, if a TO determines that a modification is needed to the NOMs methodology that TO will call for a joint review with the other TOs.

When it is agreed that changes should be made to better facilitate the achievement of the objectives, the TOs will follow the process for modification as set out in the licence as outlined below.

1.2. PROCESS TO MODIFY THE NETWORK OUTPUT MEASURES METHODOLOGY

Licence conditions 2L.10 and 2L.11 state that the licensee may make a modification to the NOMs methodology after:

a. Consulting with other Transmission Licensees to which this condition applies and with any other interested parties, allowing them a period of at least 28 days within which to make written representations with respect to the TO's modification proposal.

b. Submitting to the Authority a report that contains all of the matters that are listed below:

   i. a statement of the proposed modification to the NOMs methodology;
   ii. a full and fair summary of any representations that were made to the licensee pursuant to paragraph 2L.10(a) and were not withdrawn;
   iii. an explanation of any changes that the TO has made to its modification proposal as a consequence of representations ;
   iv. an explanation of how, in the licensee's opinion, the proposed modification, if made, would better facilitate the achievement of the NOMs methodology objectives;
   v. a presentation of the data and other relevant information (including historical data, which should be provide, where reasonably practicable, for a period of at least ten years prior to the data of the modification proposal) that the licensee has used for the purpose of developing the proposed modification ;
   vi. a presentation of any changes to the Network Replacement Outputs, as set out in the tables in Special Licence Condition 2M (Specification of Network Replacement Outputs) that are necessary as a result of the proposed modification to the NOMs methodology ; and
   A timetable for the implementation of the proposed modification, including an implementation date

2. USING THE NETWORK OUTPUT MEASURES

The TOs' NOMs are used internally to enhance current asset management processes and understanding of business drivers. This is especially in relation to the development, maintenance and operation of our networks and in assessing future network expenditure. They also enable performance assessment and monitoring as per Objective A of the NOMs.

In addition to this common methodology statement, the TOs have developed Network Asset Risk Annexes (NARAs, one for NGET, another for SHET and SPT) as well as Licensee Specific Appendices (LSAs) which describe in more detail how they use the Condition, Risk and Replacement Output NOMs within their respective businesses. The LSAs are not publicly available as each TO's assets and operations remain confidential. However, they have been submitted individually to Ofgem for review and approval.

Under RIIO-T1, the TOs have each developed integrated business plans which are supported by a suite of mechanisms designed to help manage the uncertainty that the electricity industry faces in the coming years. These plans forecast the capital and operational works which will be carried out; much of which is focused on maintaining performance of our assets through replacement, refurbishment and maintenance. These activities influence the health of an asset and as such the Network Condition, Network Risk and Network Replacement Output Measures.

Through the delivery of our business plans, the TOs' intention is to improve our safety and environmental performance whilst maintaining reliability (in terms of Energy Not Supplied) at current levels. These activities are targeted at delivering stakeholders' requirements, from connecting new supplies to providing a safe and reliable service.

The TOs' business plans are designed to manage the ongoing safety, reliability and environmental performance of our networks. The potential customer impact associated with the deteriorating performance of assets towards the end of their useful life continues to drive a programme of interventions on our transmission network assets.

The TOs manage interventions on our equipment to ensure that:

a. The number, severity and criticality of equipment failures are acceptable to the TOs and our stakeholders
b. Long term replacement plans can be achieved without having an unacceptable impact on reliability, availability, quality of supply, health, safety and environmental performance, and transmission constraints
c. Long term cost forecasts are within acceptable levels for efficient deliverability, procurement and financing requirements

The available interventions for managing the performance of assets range from routine maintenance to full replacement. At the highest level, there are four options for intervention for each lead plant type which have the following definitions:

- Repair – Activities which takes place on detection of a defect or after a fault and return the asset to its pre-fault condition and asset life
- Maintenance – Activities to achieve asset life and ensure asset performance. Maintenance would not be expected to extend asset life
- Refurbishment – Activities that change asset condition and/or extend asset life
- Replacement – Replace an asset in its entirety that is in a state requiring replacement.

2.1. DECISION MAKING

Interventions are undertaken to ensure the longevity and performance of the TOs' networks. Without effective management of these activities, and understanding the related interactions between them, the TOs would, in time, experience degradation of network outputs which would have a significant detrimental impact on the capability of the network.

Figure 2 shows how the process by which elements of NOMs feed into a non-load related investment plan. Asset Information (e.g. condition, performance) is turned into a Probability of Failure (PoF) value which represents the Network Asset Condition. These PoFs are combined with a monetised Consequence of Failure to determine the Network Risk measure. When combined with other factors (e.g. outages, resources), the Network Replacement Output Measure can be determined. The TOs can then ensure that their proposed work plan achieves desired levels of risk or risk reduction.

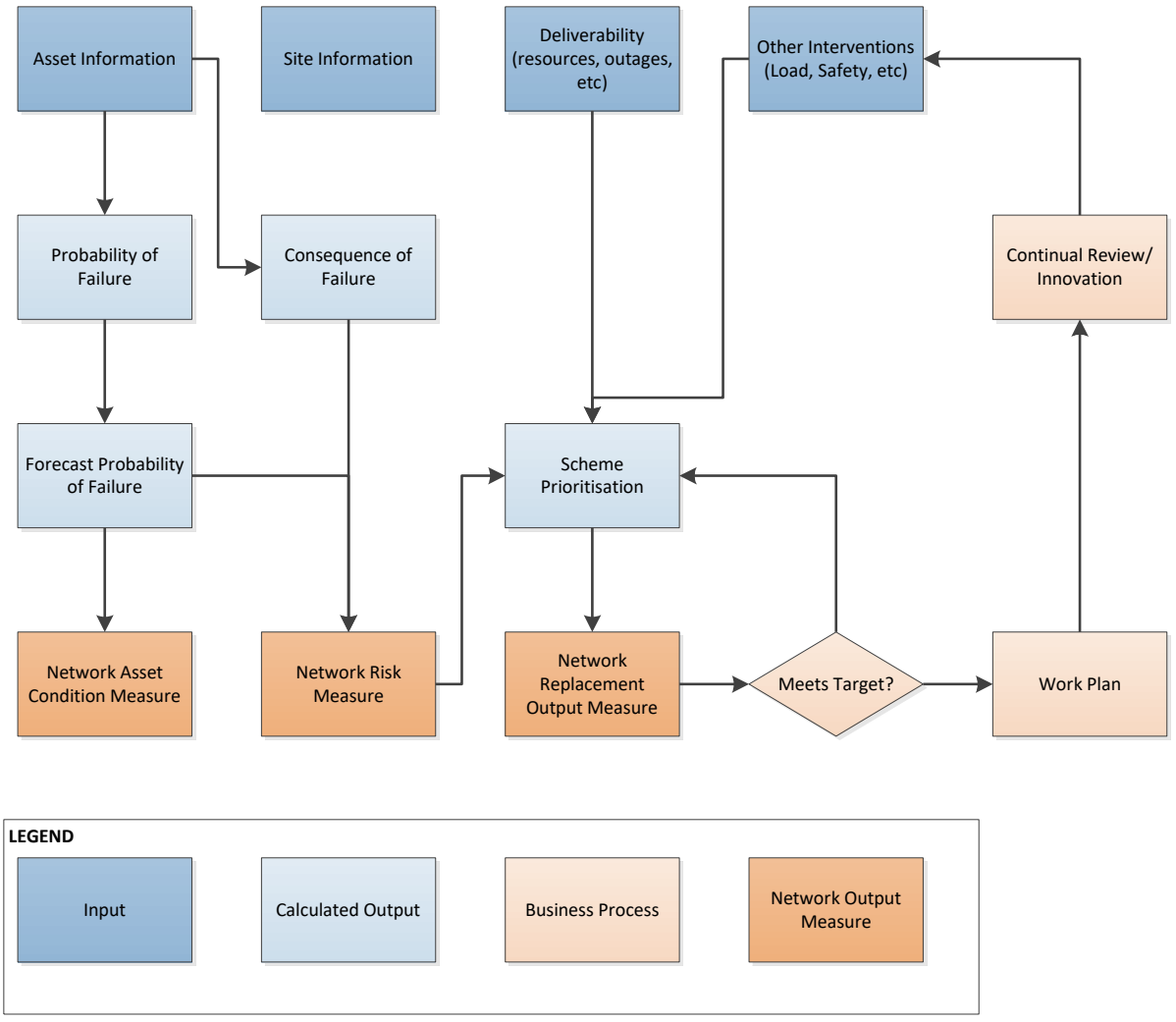

Figure 2

Network Risk has been developed in a way that ensures a consistent understanding of risk across all asset types. It takes into account changes to asset populations, including load and non-load related replacement volumes.

The Network Risk is one of the main factors which influence the Network Replacement Outputs, providing Ofgem with the ability to monitor and assess the TOs' asset management performance. The non-load related targets for the Network Replacement Outputs are coded into the respective licences for each TO in Special Licence Condition 2M. These targets will be converted into monetised risk values. Monetised risk values may be used at the end of the period to gauge a licensees delivery against its targets.

In order to undertake cost benefit analysis using this network risk, the NOMs methodology will be used to derive the monetised asset risk reduction that can be expected with and without an intervention over the lifetime of the intervention. This will enable the relative risk reduction to be compared between different intervention costs (for example replacement vrs refurbishment) and different assets as shown in Figure 3.

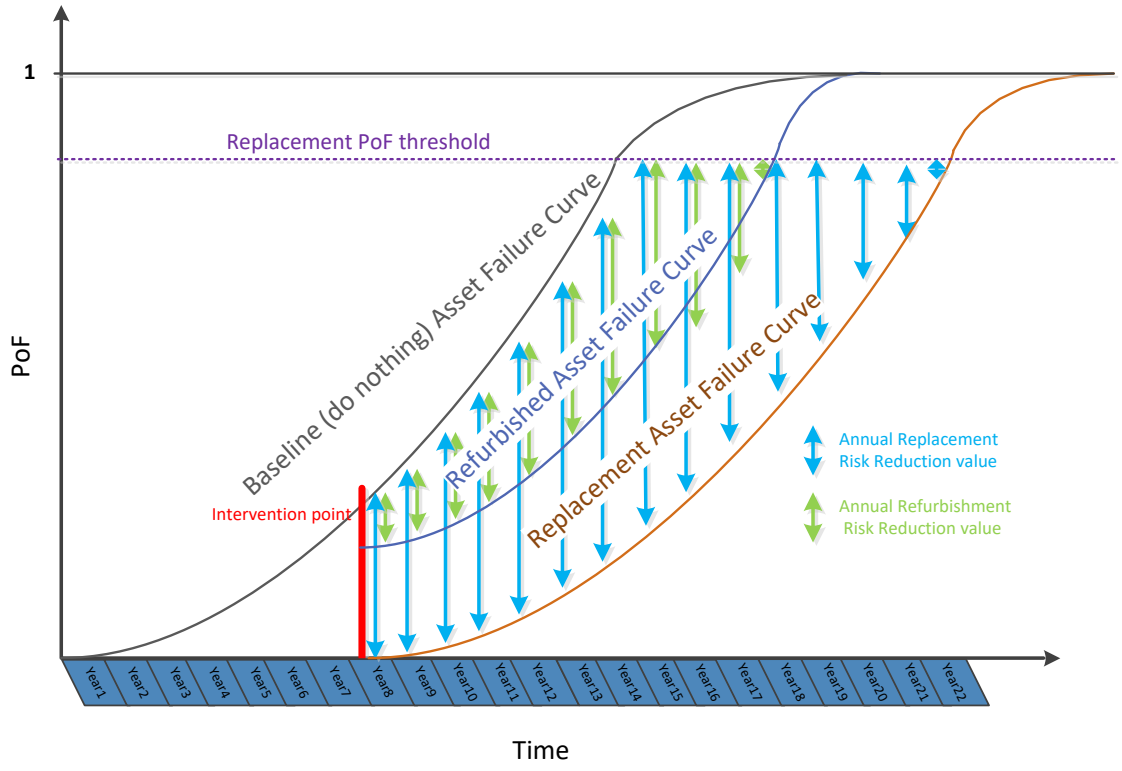

Figure 3

The area between the grey and blue curves represented by the green arrows correspond to the lifetime benefit achieved through refurbishing an asset, and the area between the grey and orange curves which are represented by the light blue arrows correspond to the lifetime benefit achieved through replacing an asset.

Thus the avoided risk value of each intervention can be introduced into the CBA analysis as a benefit subject to the duration that the benefit lasts for particular interventions.

2.1.1. RISK TRADING MODEL

The Risk Trading Model will calculate the monetised risk for each asset and aggregate to give the total Network Risk. It will reflect the processes and calculations described within this methodology and associated appendices.

The Risk Trading Model (RTM) has been developed with the aim that it will be used to assist in planning and prioritising non-load related interventions to be undertaken on assets within the transmission network between

a start year (Y_o) and an end year (Y_n). The RTM will also fulfil NOMs Objective B, and enable the assessment of historical and forecast network expenditure in this area on the licensee's Transmission System.

The RTM is based upon a catalogue of the assets in each TOs transmission network. Included within this catalogue are specific details of the assets, along with the associated Probability of Failure in the start year (PoF_{Y0}), the monetised Consequence of Failure (CoF) and a forecast Probability of Failure in the end year (PoF_{Yn}). The RTM investigates the impact that different investment plans have upon the monetised risk of the individual asset, asset category and the whole network at Y_n. Figure 4 outlines the data used and steps applied within the RTM.

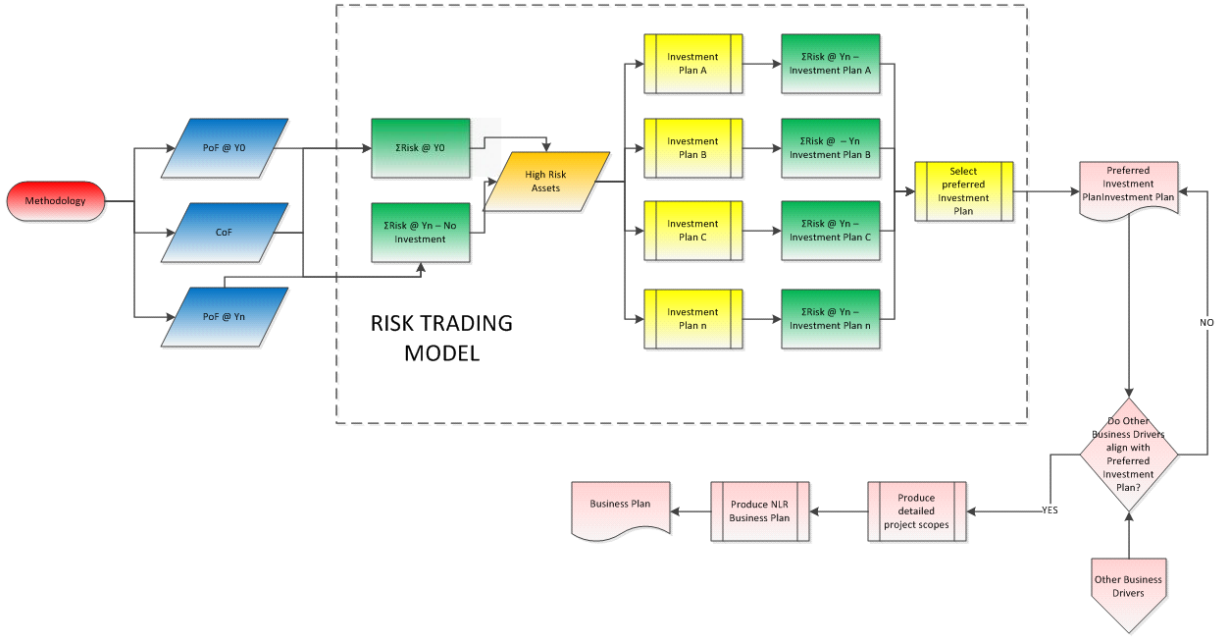

Figure 4

2.2. NETWORK ASSET CONDITION MEASURE

2.2.1. LICENCE REQUIREMENTS

Paragraph 2L.4(a) of Special Licence Condition requires the TOs to enable the evaluation of:

"the current condition of the Network Assets, the reliability of the Network Assets, and the predicted rate of degradation in the condition of the Network Assets, which is relevant to assessing the present and future ability of the Network Assets to perform their function"

The key elements from this Special Licence Condition are:

a. Current condition of the Network Assets

b. Predicted rate of degradation

2.2.2. METHODOLOGY

The TOs use Probability of Failure (PoF) as a measure of Asset Condition, as shown in Figure 5. PoF represents the probability that an asset failure will occur in the next time period. It is generated from an underlying parametric probability distribution or failure curve. PoF is influenced by a number of factors, including time, duty and condition. More detail on the specific calculations for each asset type can be found in the Network Asset Risk Appendices and the TO Licensee Specific Appendices.

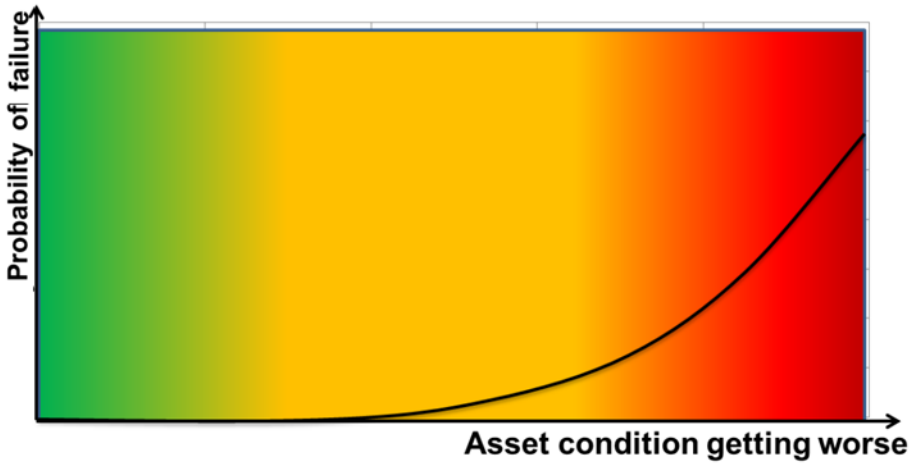

Figure 5

2.2.3. ENSURING CONSISTENCY

All TOs use the same high-level approach for calculation of the PoF. However, there may be TO specific issues which may result in small changes to the methodologies. These are shown in the Network Asset Risk Appendices and are fully justified and explained within the relevant TO Licensee Specific Appendix.

2.3. NETWORK RISK MEASURE

2.3.1. LICENCE REQUIREMENTS

Paragraph 2L.4(b) of Special Licence Condition requires the TOs to enable the evaluation of:

"the overall level of risk to the reliability of the licensee's Transmission System that results from the condition of the Network Assets and the interdependence between the Network Assets"

The key elements from this Special Licence Condition are:

a. Overall Level of Risk
b. Condition of network Assets

2.3.2. METHODOLOGY

Modelling the deterioration of the condition of components or the entire asset is used to identify failure ,odes that may cause a material failure of the asset. These failure modes can lead to a reduction of the reliability of the transmission network which the Transmission Owners strive to minimise by quantifying the risks of these failure modes as an Asset Risk Value.

As shown in Equation 1, the Asset Risk is the sum of the expected values of each consequence associated with that asset and a function of the probability of each failure mode occurring.

This methodology is based on conditional risk due to factors within the asset such as corrosion, defects, etc. It does not consider Non-Condition Risks such as storms blowing trees down onto overheadlines or vehicles crashing into substation transformers for example.

For reasons of economic efficiency, TOs do not consider every possible failure mode and consequence, only those which are materially significant and based on condition risk. TOs' assessment of material significance is based upon their experience and consequential information set. TOs have different information sets and therefore have made different decisions, within the same overall methodology, about what should be measured or calculated from first principles and what must be estimated. More information can be found in the NARAs.

For any given asset, a measure of the risk associated with it is the Asset Risk (AR), given by:

$$AR = \sum_{j=1}^{n} PoF_j \times CoF_j$$

Equation 1

where:

PoF_j = Probability of Failure *j* occurring during a given time period

CoF_j = the monetised Consequence of Failure *j*

n = the number of Failures associated with Asset

For the network, a measure of the risk associated with it is the Network Risk (NR), given by:

$$NR = \sum_{k=1}^{n} AR_k$$

Equation 2

where:

AR_k = the Asset Risk associated with Asset, k.

n = the number of Assets on the Network

Consequence is the monetised value for each of the underlying Financial, Safety, System and Environmental components of a particular consequence e.g. Transformer Fire. A Consequence can be caused by more than one Failure Mode. A failure mode being a cause of failure or one possible way a system can fail such as; paper insulation degradation in transformers will cause increased wear and potential interaction between otherwise

isolated components. A Consequence itself however, can only occur once during the next time period. For example, an Asset or a particular component is only irreparably damaged once. The descriptions of both Failure mode and Consequence is elaborated further in the NARA.

2.3.3. ENSURING CONSISTENCY

All TOs use broadly the same methodologies for calculation of the CoF, as shown in the Network Asset Risk Appendices (NARAs). However, there may be TO specific issues which may result in small changes to the methodologies. These are shown in the NARAs and are fully justified and explained within the relevant Licensee Specific Appendix (LSA).

2.4. NETWORK PERFORMANCE MEASURE

Network Performance is currently monitored through the Average Circuit Unreliability (ACU) metric, which represents network unavailability as a result of asset unreliability. This metric records the impact of Functional Failures and is used to understand the impact of unreliability on the TOs' networks.

Work has been undertaken to further understand the relationship between asset condition and network performance. The ACU is presented in a format that disaggregates the metric by equipment group and then by asset condition. Figure 6 shows the conceptual relationship between Energy Not Supplied events and other network performance metrics. The TOs are continuously developing their understanding of the relationship between Asset Health and Network Performance.

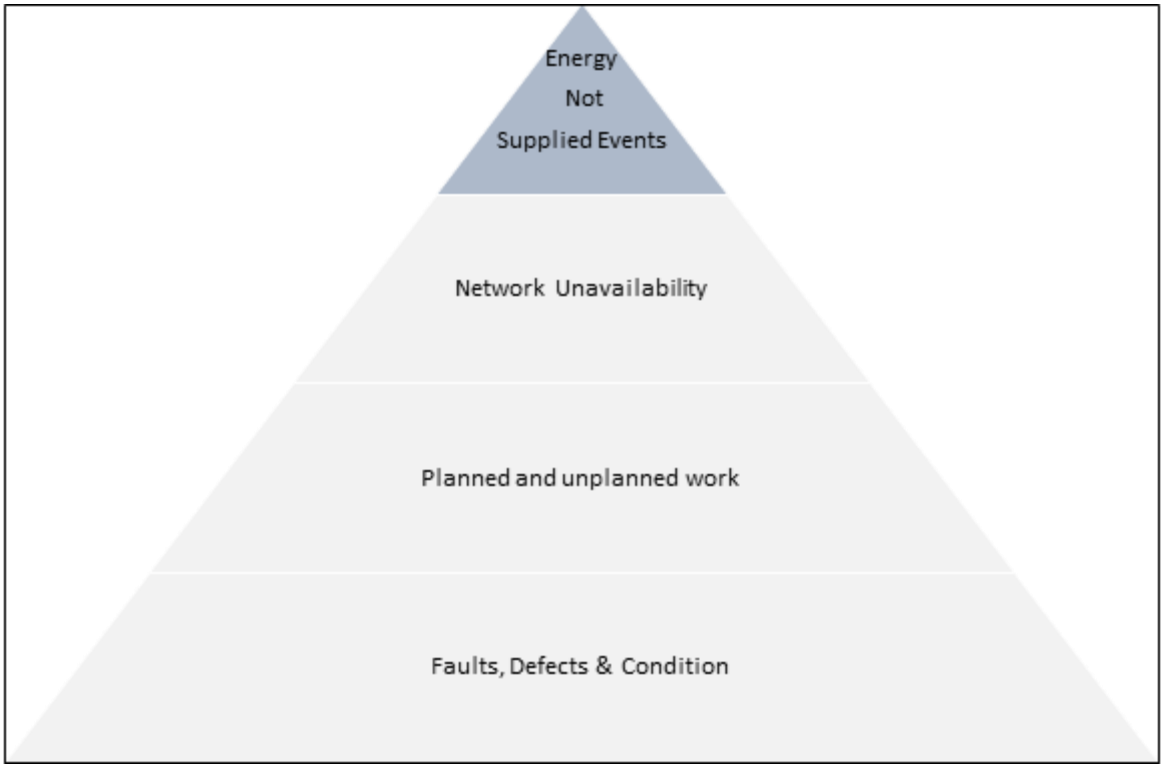

Figure 6

2.4.1. LICENCE REQUIREMENTS

Paragraph 2L.4(c) of Special Licence Condition requires the TOs to enable the evaluation of:

"Those aspects of the technical performance of the TO's Transmission system which have a direct impact on the reliability and cost of services provided the TO as part of its Transmission Business".

Objective E of the NOMs is "the assessment of customer satisfaction derived from the services provided by the licensee as part of its Transmission business"

The key elements from this Special Licence Condition and the NOMs Objective are:

a. Performance of the TO's Transmission system

b. Direct impact on the reliability and cost of the services

2.4.2. METHODOLOGY

Network Performance is a key output for the customers of the TOs. To provide a full picture on Network Performance, it is necessary to consider a number of complementary performance measures. This is because some measures consider events only and some consider a combination of event and duration.

Reduced reliability of the Transmission network increases the risk of loss of supply for directly connected customers and increased costs to market participants which impact the consumer. An increased number of loss of supply events creates a cost of inconvenience to the general consumer and in extreme cases will result in a significant impact upon the economy.

Average Circuit Unreliability (ACU) is derived from the unavailability of the network due to outages occurring as a result of unreliability events which cannot be deferred until the next planned intervention and is defined in Equation 3 below.

$$\frac{Total\ Duration\ of\ Repair\ (cumulative\ across\ circuit)}{Number\ of\ Circuits \times Duration\ of\ reported\ time\ period}$$

Equation 3

Duration in the context of ACU is a continuous number and is not rounded or truncated at any stage of the calculation, thus no errors are introduced into the calculation.

The monthly duration is calculated using a differing number of days in a month and so any calculation to derive a yearly number will require a suitable weighting of monthly values to account for this.

The outages which are classified as being included within the definition of ACU are:

a. Enforced unreliability outages taken at less than 24 hours' notice (otherwise known as unplanned unavailability)
b. Planned unreliability outages taken after 24 hours' notice

All unreliability related outages are included within the definition of ACU. The definition above assumes that no outages are planned with less than 24 hours' notice as any such outage would fall into part a. in the definition above.

The TOs have investigated whether the Fault and Failure data provides a statistically significant dataset to derive correlations with asset condition. The actual number of Faults and Failures is very small across all the TOs. This is a result of:

a. Actual population sizes of the assets. The population is not large enough to experience a great number of reliability related Faults and Failures

b. Asset management approach within the business. The TOs maintain assets to manage the number of faults experienced and aim to replace before failure using Risk to prioritise asset replacement candidates. This means many Faults and Failures that might occur are avoided.

The number of Faults and Failures has proven insufficient to enable accurate correlations with asset condition. Details of the investigations undertaken by each TO are included in the existing respective Licensee Specific Appendices.

By looking at Functional Failures, there is a greater set of data which can be used for correlation with asset condition. Functional Failures include those unreliability related outages which are used to determine ACU.

There is limited historical condition information to provide correlation with Functional Failures. As datasets grow we will gain better understanding of whether there is a correlation and the extend of any correlation.

with asset condition The investigations undertaken by each TO include the analysis undertaken to identify correlations between asset unreliability and asset condition are detailed in the Licensee Specific Appendices.

2.4.3. ENSURING CONSISTENCY

The ACU is calculated consistently using the same definitions in line with the RIGs for all TOs.

The calculation to determine Energy Not Supplied for incentivised loss of supply events according to transmission licence condition 3C is based upon a joint methodology statement[1]. This was developed jointly between all transmission TOs and is therefore applied consistently.

2.5. NETWORK CAPABILITY MEASURE

Network Capability is used to understand the localised demand driven need for developing Transmission infrastructure. Utilisation is represented as demand or generation as a percentage of capacity. The Capability measure records the impact of specific schemes on the capability for each boundary, using thermal, voltage and stability incremental capability across each boundary.

[1] https://www.ofgem.gov.uk/system/files/docs/2016/05/joint_to_methodology_for_estimating_energy_not_supplied_issue_3_september_2015.pdf

2.5.1. LICENCE REQUIREMENTS

Paragraph 2L.4(d) of the Special Licence Condition requires the TOs to enable the evaluation of:

"The Network Capability measure, which relates to the level of the capability and utilisation of the TO's Transmission System at entry and exit points and to other network capability and utilisation factors"

The key elements from this Special Licence Condition are:

1. Information about Transmission System capability
2. Information about Transmission System utilisation

2.5.2. METHODOLOGY

The TOs report on Transmission system capability as part of the Transmission RRP which monitors the existing Transmission capacity being provided by the TOs on the NETS.

Likewise, the Transmission RRP requires the individual TOs to collect information relating to more localised demand driven needs for developing transmission infrastructure. This is presented in Table 5.5 with utilisation being represented as demand as a percentage of capacity. This shows the relationship between localised demand and capacity and hence provides a proxy measure for utilisation.

Adopting these measures ensures consistency in reporting and interpretation of requirements across all TOs.

2.5.3. PROVISION OF INFORMATION ON VOLTAGE AND STABILITY (THERMAL)

Information is reported in the Electricity Ten Year Statement (ETYS[2]) at a boundary level. This boundary capability is calculated based on the most onerous limitation whether this is thermal or voltage related.

Where stability constrains boundary capability this data will be provided where it is available.

Currently, Transmission RRP Table 5.4 reports present year boundary capability and incremental capability for the reinforcement completed in the present year.

2.5.4. ENSURING CONSISTENCY

Capability and utilisation is reported by the TOs in a consistent manner according to the RIGS. As described earlier, demand is represented as a percentage of capacity, hence ensuring a consistency of reporting despite the differing scales of the respective TOs' networks.

[2] https://www.nationalgrid.com/uk/publications/electricity-ten-year-statement-etys

2.6. NETWORK REPLACEMENT OUTPUTS MEASURE

2.6.1. RIIO-T1 TARGET SETTING PROCESS

Figure 7 shows the process for setting the RIIO-T1 network replacement output targets. Because TOs have changed the way in which we calculate Risk, this differs significantly to the methodology described in the Network Asset Risk Appendices. Details can be found in previous versions of this document.

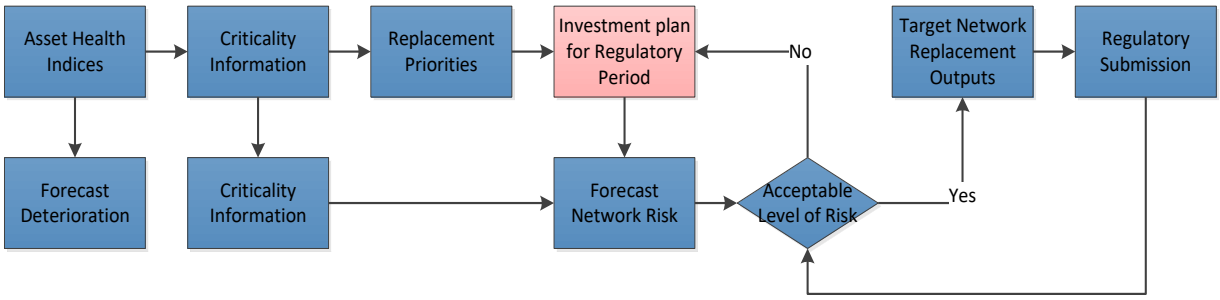

Figure 7

The TOs actively develop their asset management capabilities. The risk and criticality approach targets asset interventions on assets in poorest condition with the highest consequences of failures. One of the fundamental parts of this approach is the TOs' ability to forecast asset degradation, supported by extensive knowledge of the assets informed through innovation, failure investigations, forensic investigations, condition monitoring and assessment, family history, international experience and asset performance data.

For the RIIO-T1 submission, the network replacement output targets encoded into Condition 2M of the Transmission Licence were set based on the forecast of expected asset Replacement Priorities (Network Risk) at 31 March 2021. To generate this forecast of expected Replacement Priorities the TOs used forecast asset degradation and their forecast investment plans for the RIIO-T1 period. As part of the RIIO-T1 price control review, Ofgem and their consultants assessed the TOs forecast asset degradation and forecast investment plans and based on this assessment adopted the asset Replacement Priorities at 31 March 2021 as the basis of the network replacement output targets.

Prior to submission of RIIO-T1 business plans, stakeholder engagement indicated that consumers were satisfied with existing levels of reliability. Forecast investment plans were therefore developed to keep the network risk at a similar level at the end of RIIO-T1, as it was at the beginning of RIIO-T1.

There are two principal sources of uncertainty around forecast network risk. These are:

i) Uncertainty associated with the forecasting of asset degradation;
ii) Uncertainty associated with unexpected type faults.

Asset degradation is inherently uncertain and probabilistic modelling techniques are used to forecast future condition. This is combined with information on asset Criticality to calculate a forecast of Replacement Priority.

The forecast Replacement Priorities at 31 March 2021 were based on a 50th percentile, giving the median value and thus expected forecast of network risk.

To ensure the uncertainty in future asset condition was included in the assessment of forecast network risk by Ofgem and their consultants, confidence levels at 25% and 75% were additionally provided to Ofgem to provide an understanding of distribution of uncertainty around the expected Replacement Priorities.

Unexpected type faults cannot be forecast but can have a significant impact on network risk, cause significant costs and lead to disruption of the forecast capital programme. It would not be sensible to model this risk probabilistically so these were not included in the forecast of Replacement Priorities.

Throughout the eight year RIIO-T1 period, the TOs are learning more about their assets as they age and experience new duty cycles. Further assets will enter the wear-out period of life which will allow collection of new condition information. In addition it is likely failures will occur which will reveal new degradation mechanisms which are currently unknown.

This new condition information and new degradation mechanisms will feed into the degradation modelling and asset technical lives. In addition, the TOs continue to seek new cost-beneficial intervention options to manage the evolving condition of the assets. In some cases this will allow some life extension and in other cases this may cause life reductions.

2.6.2. TRANSITION TO NEW METHODOLOGY

NOMs are a mechanism that provides a means to monitor and assess the network management outcomes that the transmission network companies deliver. They represent the service delivery resulting from companies' asset interventions, and can be considered as a forward-looking indicator of network performance.

The transmission licence specifies NOMs relating to the position at the end of the price control period. This constitutes a matrix specifying the target number of units, per asset category, that fall within a replacement priority group remaining on the system at the end of the price control, taking account of load-related asset changes by excluding them. Where the Replacement Priority is a list of assets, grouped by equipment type and voltage, that prioritise replacement based on the Asset Health Index and Criticality.

The transmission licensees will be assessed against an absolute level of network monetised risk, and the NOMs incentive mechanism will reward justified delivery of a lower absolute risk compared to target, and penalise unjustified delivery of a higher absolute risk compared to target.

As mentioned in Section 1, the Network Replacement Outputs Target set in Special Licence Condition 2L will be converted into a Monetised Risk value at a network level. Performance at the end of the price control will be measured against this monetised value. The TOs will carry out this target translation, or "rebasing", using the following principles:

i) Rebased targets shall be as equally challenging as the original ones for the TOs to meet and outperform,
ii) Same principles shall be applied as those used in RIIO-T1 Business Plan, and
iii) Direct translation of original investment plan shall be made wherever appropriate.

3. REPORTING TO THE AUTHORITY

3.1. LICENCE REQUIREMENTS

The NOMs will be reported to Ofgem as part of the annual Transmission Regulatory Reporting Packs (RRP) as required in Standard Licence Condition B15: Regulatory Instructions and Guidance (RIGs).

Licence Condition 2L.6 requires that the TOs provide information (whether historical, current or forward-looking) about the NOMs supported by such relevant other data and examples of network modelling, as may be specified for the purposes of this condition in any RIGs that have been issued by the Authority in accordance with the provisions of Standard Licence Condition B15.

In addition to the submitted tables, the TOs provide a narrative which explains changes to the outputs from the previous year.

3.1.1. REPORTING TIMESCALES

The reporting year for the provision of information is from 1 April to 31 March the following calendar year. The information required under the RIGs will be provided not later than 31 July following the end of the relevant reporting year.

For the RIIO-T1 period, the first reporting period was 1 April 2013 to 31 March 2014.

3.1.2. DATA ASSURANCE

Licence Condition B23 requires each TO to undertake processes and activities for the purpose of reducing the risk, and subsequent impact and consequences, of any inaccurate or incomplete reporting, or any misreporting, of information to the Authority.

To ensure compliance with this licence condition, each TO carries out risk assessments to understand the implications of reporting inaccurate, inconsistent or incomplete data. Each NOM table reported in the RRP has undergone such a risk assessment. Where improvements can be made to data systems or processes, actions are planned that are proportionate to the risk of a submission in order to reduce the impact of inaccuracies in the submissions.

In providing data the TOs have developed work instructions for each table to be submitted to ensure a consistent approach.

Data concerning the asset inventory, condition scoring and criticality information is specific to each TO. Details about the type and quantity of data are described in each Licensee Specific Appendix.

Specifically, these describe the data that informs Network Asset Condition and how it is used for specific assets. They indicate the volume of available data and whether any data has to be inferred. They explain whether there is any blanket replacement of certain assets and associated reasons. These also describe how any limitations in the data affect the confidence in scoring for probability and consequence of failure and how any uncertainties can be quantified.

3.2. NETWORK ASSET CONDITION MEASURE

Asset Health for each of the lead assets is reviewed each year and reported to Ofgem in *Table 6.15.1_NOMs_detail* of the Transmission RRP. This information is reported for the 400 kV, 275 kV, and 132 kV Transmission networks. The information is further split into criticality and replacement prioritisation.

Amendments to this table will be required to support the reporting of PoF rather than Health Indices.

3.3. NETWORK RISK MEASURE

Network Risk is reviewed each year but is not currently explicitly reported to Ofgem.

3.4. NETWORK PERFORMANCE MEASURE

The TOs report a comprehensive set of Network Performance measures in the form of Energy Not Supplied (Table 6.3), Average Circuit Unavailability (Table 5.10) as well as Faults and Failures information (Table 5.2) with associated commentary through the Transmission RRP.

For ACU, the total number of circuits used in this calculation varies by TO and will vary from year to year as the networks are modified. For this reason, the number of circuits used as part of the ACU calculation is reported as at 31 March each year.

3.5. NETWORK CAPABILITY MEASURE

Tables 5.3 and 5.4 of the Transmission RRP reflect the capability requirement and boundary capability for all system boundaries. Table 5.5 reflects the utilisation requirement.

Table 5.3 collects information on Transmission capacity against required transfer levels at key parts of the Transmission system.

Actual capability information is provided in Table 5.4 and reflects the impact of specific schemes on the capability for each boundary. For each scheme the thermal, voltage and stability incremental capability across each boundary is given. In addition, the Table shows the capabilities at the start of the reporting period and the final overall capability (based on all schemes). The RIGs provide the rules for populating Table 5.4.

The rules for populating Table 5.5 are also taken form the RIGs. Information will be used from the most recent business planning studies. Further rules are as follows:

a. Peak Demand: the maximum demand of the demand group at the substation
b. Maintenance Period Demand: as defined in the NETS SQSS
c. n-1 Capacity: the first circuit outage condition as defined in the NETS SQSS
d. n-2 Capacity (300 MW demand groups only): the second circuit outage condition as set out in the NETS SQSS. This is only applicable for substations where the peak group demand is greater than 300 MW.

3.6. NETWORK REPLACEMENT OUTPUT MEASURE

Table 6.15.1 currently captures the TOs' performance against the targets set in Special Licence Condition 2L

4. COMPARATIVE ANALYSIS

Within this section the Transmission Licensees have considered the following parts of the Licence Condition 2L3c:

The Network Output Measures shall be designed to facilitate the comparative analysis over time between:

i. Geographic areas of, and network assets within the Licensee's transmission system
ii. Transmission systems within Great Britain
iii. Transmission systems within Great Britain and within other countries
iv. Transmission systems and Distribution Systems within Great Britain

The Network Output Measures Methodology has been designed to enable comparability of network. The constituent elements of Consequence recognise site-specific differences but are otherwise the same.

By developing the Network Output Measures Methodology across the Transmission Licensees, the Network Output Measures are produced in the same format to allow comparative analysis across Transmission Licensees.

Due to the inherent differences between the Licensees' and their networks, there remains differences in the detailed calculations behind Network Condition. However, by continually sharing information across the Transmission Licensees with the aim of calibrating the Network Output Measures this will enable comparison across the Transmission Licensees.

In addition to the development of the Network Output Measures, the three Transmission Licensees have researched methods used to report similar measures within Great Britain and other countries. Examples of these systems are Condition Based Risk Management, Health Indices and Criticality Indices. Whilst adopting a Methodology used by other Transmission Companies would indicate the outputs will have the same definitions, the evidence collected shows these methodologies are highly configurable so the companies using them can align the measures to their asset base and statutory, regulatory and business requirements.

Throughout the development of the Network Output Measures, the Transmission Licensees reviewed the RIIO-ED1 Network Output Measures to determine where consistency in reporting across Transmission and Distribution is viable. Both Electricity DNOs and Gas Distribution Networks (GDNs) have also been key stakeholders throughout the Development of these NOMs. The Transmission Network Output Measures Methodology has similar features to the RIIO-ED1 Distribution Network Output Measures by looking at an overall network risk picture. However, due to the differing nature of the networks, differing network design standards and consequence factors, these methodologies are not interchangeable.

5. UNCERTAINTY

Statistical uncertainty accounts for random fluctuations in measurement, or to account for an error in the methods used to make measurements. Random fluctuations follow a normal distribution, and the standard deviation can be used to describe the uncertainty within the distribution i.e. the range either side of the mean. Note that statistical uncertainty cannot account for systemic error, which can occur when making assumptions, or using a reference point which is not correctly calibrated.

The mean ($\bar{x}$) is calculated using:

Equation 4

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

The standard deviation (σ_x) is calculated using:

Equation 5

$$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Statistical uncertainty can be considered at varying levels of abstraction, so to be consistent with the development of the other aspects of the NOMs methodology, it is proposed to consider statistical uncertainty at a lead asset level.

Each lead asset will have its own standard deviation, demonstrating where the inputs (including time, duty and condition information) for the probability and consequence calculations differ from the mean.

The process that occurs within the probability and consequence calculations determine how the total standard deviation is calculated for each lead asset. This can be calculated using Table 1 which demonstrates how to calculate the total standard deviation when the process involves addition, multiplication and indexes:

Equation for normal distribution	Standard deviation
$d = a + b - c$	$\sigma_d = \sqrt{\sigma_a^2 + \sigma_b^2 + \sigma_c^2}$
$d = \frac{ab}{c}$	$\frac{\sigma_d}{d} = \sqrt{(\frac{\sigma_a}{a})^2 + (\frac{\sigma_b}{b})^2 + (\frac{\sigma_c}{c})^2}$
$d = \frac{a^l b^m}{c^n}$	$\frac{\sigma_d}{d} = \sqrt{(l\frac{\sigma_a}{a})^2 + (m\frac{\sigma_b}{b})^2 + (n\frac{\sigma_c}{c})^2}$

Table 1

The standard error is used when relating a sample size to a population to indicate the relationship between the true mean of the population, and the mean of the sample population.

Equation 6

$$SE = \frac{\sigma}{\sqrt{N}}$$

Standard errors provide simple measures of uncertainty in a value and are often used because:

1. If the standard error of several individual quantities is known, then the standard error of some function of the quantities can be easily calculated in many cases

2. Where the probability distribution of the value is known, it can be used to calculate a good approximation to an exact confidence interval

3. As the sample size tends to infinity the central limit theorem guarantees that the sampling distribution of the mean is asymptotically normal

The standard error shall be used to determine the total uncertainty in the network risk calculation for each lead asset. The sum of these standard errors relates to the total uncertainty in the network risk calculation. Figure 8 demonstrates where the uncertainty shall be included within the network risk calculation.

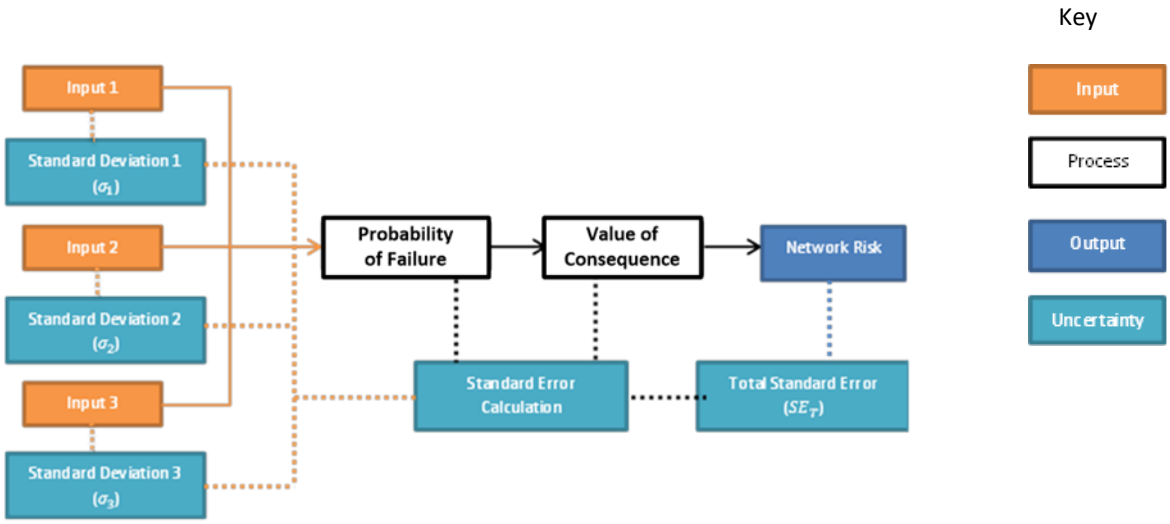

Figure 8

6. CONTINUOUS IMPROVEMENT

The TOs will continue to assess the performance of their assets and, through monitoring these metrics, will use them to develop strategies to manage asset unreliability.

The TOs will continue to review the submitted information for Network Capability.

7. EXTERNAL PUBLICATION

There are no issues with the external publication of the majority of the detailed documentation associated with Network Output Measures. However, there are a small number of Appendices which should not be published as they contain company confidential information:

- Licensee Specific Appendices associated with the Network Risk Measure
- Summary RRP tables associated with the Network Performance Measure.
- Licensee Specific Appendices and Summary RRP tables associated with the Network Capability Measure.

8. GLOSSARY

Asset Risk	Term adopted that is synonymous with Condition Risk in the Direction
Asset Class	A group of assets with similar characteristics
Asset Management	Coordinated activity of an organisation to realise value from assets
Consequence	Outcome of an event affecting objectives*
Conditional Factors	Factors that lead to an assets failure due to its physical condition
Consequence of Failure	A consequence can be caused by more than one Failure Mode. This is monetised values for the Safety, Environmental, System and Financial consequences
Cost of Consequence	The costs incurred due to a consequence of failure manifesting across a site.
Deterioration	Progressive worsening of condition
the Direction	Ofgem Direction document from April 2016
EoL Modifier	End of Life number that modifies or is modified to produce an End of life value
EoL Value	The target EoL value used for Modifies or is Modified to produce an End of Life value.
Event	Occurrence or change of a particular set of circumstances*
Failure	A component no longer does what it is designed to do. May or may not result in a fault
Failure Mode	A distinct way in which a component can fail
Fault	An asset no longer functions and intervention is required before it can be returned to service
Intervention	An activity (maintenance, refurbishment, repair or replacement) that is carried out on an asset to address one or more failure modes
Level of risk	Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood*
Licensee(s)	One or more of the TOs
Likelihood	Chance of something happening*
Load Related	Works on a transmission system required due to an increase in demand and/or generation
Modified Anticipated Life	The anticipated life value gathered from manufacturer data that is modified with respect to how much the asset is doing and where it is located.
Maximum Multiple Increment technique	Combines multiple factors together to produce a single overall factor with respect to the components factors various weightings of importance
Monetised Risk	A financial measure of risk calculated as a utility function
Network Risk	The sum of all the Asset Risk associated with assets on a TO network
Non-Conditional Factors	Factors that affect asset performance due to its operating circumstances
Principal Result	The most significant result from a collection of results taken over a period of time.
Probability of Failure	The likelihood that a Failure Mode will occur in a given time period
Probability of Consequence	The likelihood that a consequence will manifest due to a failure in each time period.
Risk	Effect of uncertainty on objectives*
Risk management	Coordinated activities to direct and control an organization with regards to risk*
Specific Degradation	Processes inside assets that give a good indication of asset failure