NETWORK OUTPUT MEASURES METHODOLOGY
Author: Scottish Power Transmission Limited

1.0 PURPOSE AND SCOPE

A Network Output Measures Methodology Statement has been produced in accordance with standard Electricity Transmission Licence Condition B17 and has been jointly developed by the three Transmission Licensees (Electricity) in the UK (National Grid, Scottish Power Transmission Limited SPTL and Scottish Hydro-Electricity SHETL).

The Methodology Statement describes the common framework (concepts and principles) which will be followed by the three Transmission Licensees in producing the Network Output Measures in each of the following four areas:

a. Network Asset Condition
b. Network Risk
c. Network Performance
d. Network Capability

In addition to the Methodology Statement, each individual Transmission Licensee has produced TO specific appendices to describe specifically how they each will produce the Network Output Measures using the common framework described in the Methodology Statement. This document includes the supporting data categories and models used to generate the Network Output Measures.

This document sets out the existing activities employed by Scottish Power as part of its Asset Management Systems and the manner in which the existing activities will be utilised to deliver the requirements under the Network Output measures Framework

As outlined in the Methodology Statement further work is required to jointly further develop the framework around Network Risk and Network Performance. The joint framework is still evolving and development work is underway within Scottish Power to establish and implement the Network Output Measures framework.

This Implementation Document and all associated documentation will continue to undergo review and revision as the Network Output Measures are regularly reviewed to ensure they are still meeting the objectives of the Licence Condition and further developments of the measures are proposed.

2.0 USING NETWORK OUTPUT MEASURES WITHIN SCOTTISH POWER

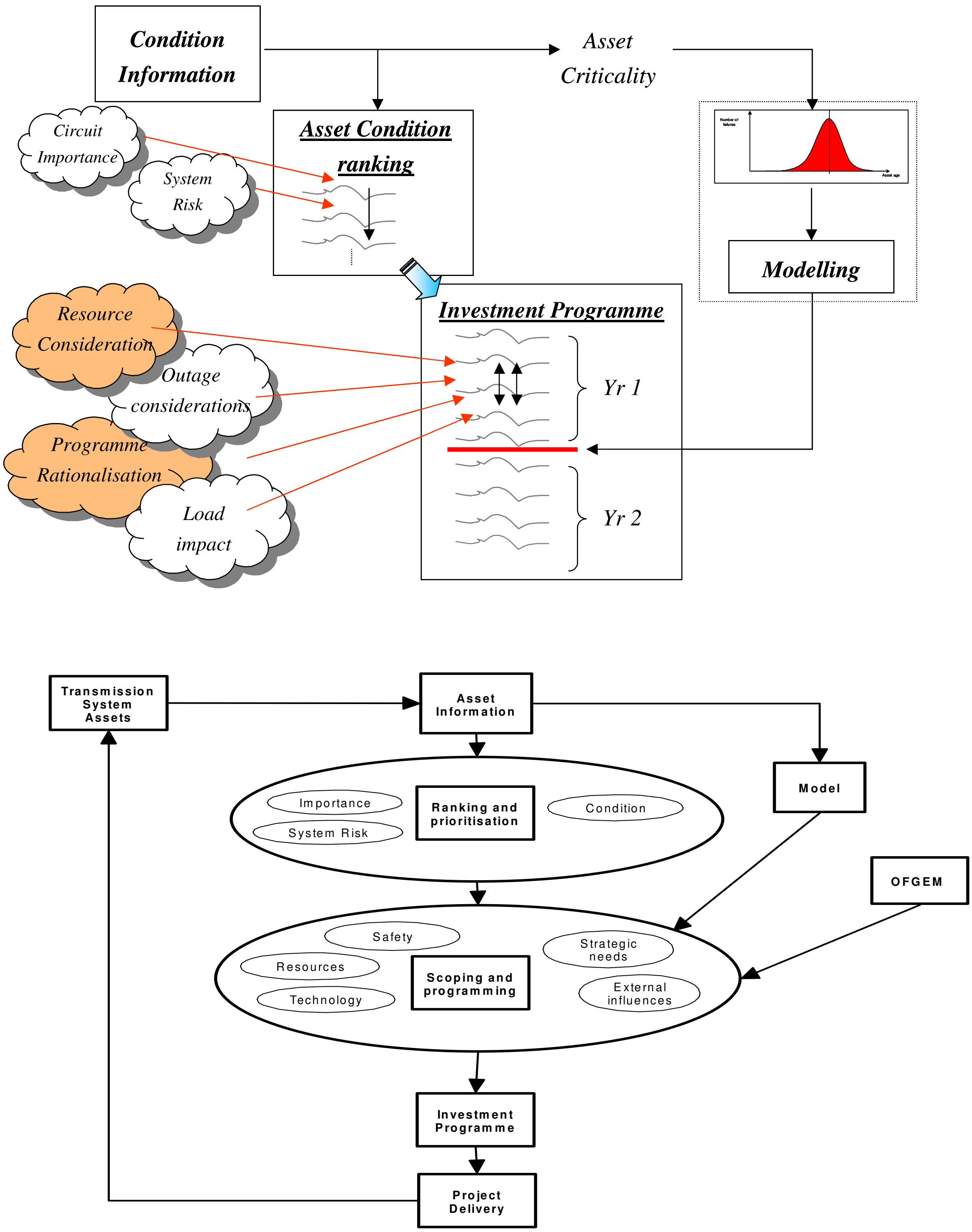
2.1 Long term Asset Replacement Planning

The asset replacement model adopted by SPTL records information relating to age, voltage and circuit parameters for the different categories of assets employed on transmission networks, including:

- Cables
- Transformers
- Overhead Lines
- Switchgear

This model is utilised to predict long-term asset replacement volumes for each asset category and thus enables early identification of potential peaks in future workload.

SPTL employ a top down modelling approach that is complemented by bottom up condition assessment. This enables the most robust engineering solutions to be presented and also addresses potential conflict between long term and short term. This is shown diagrammatically in Figure 1 below:



Condition Information
Asset Criticality
Asset Condition ranking
Circuit Importance
System Risk
Modelling
Investment Programme
Resource Consideration
Outage considerations
Programme Rationalisation
Load impact
Yr 1
Yr 2
Transmission System Assets
Asset Information
Model
Importance
System Risk
Ranking and prioritisation
Condition
OFGEM
Safety
Resources
Technology
Scoping and programming
Strategic needs
External influences
Investment Programme
Project Delivery

Figure 1

The planning process includes a review of the impact of factors such as legal and licence compliance, asset risk, asset turnover and age profiles. Figure 2 below provides a pictorial overview of the individual stages within the process.

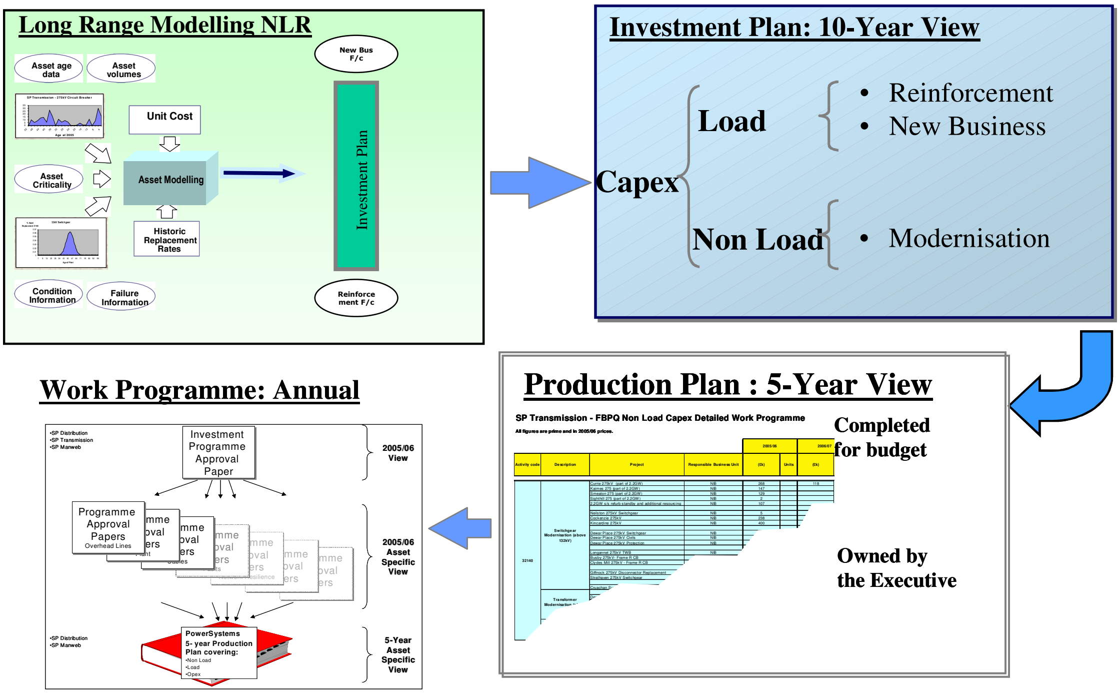


Figure 2

The main philosophy in developing the forecast expenditure is to utilise accurate and sufficiently detailed asset information (including condition data), together with realistic plant costs, to provide inputs into a recognised statistical modelling programme.

The SPTL model addresses the increased complexity of transmission assets and provides additional flexibility. The model has the advantage of accommodating the different drivers and analysis requirements of transmission networks and the characteristics and information for individual assets.

The model provides the facility to:

- Forecast expenditure requirements
- Forecast evolution of condition and replacement volumes
- Assess the impact of alternative asset management policies

The model has the flexibility to accept a variety of inputs, from basic information applied globally to all asset types, to specifically applied information on condition, replacement characteristics, manual replacement and asset criticality.

It is essential when modelling that all major network assets are represented in the modelling process and to ensure this is the case, the following asset groups are employed:

- Switchgear
- Transformers
- Overhead Lines
- Cables

These groups incorporate the associated civil and ancillary equipment, together with environmental and planning requirements.

2.2 Short to Medium Term Asset Replacement Planning

SPTL's strategy is designed to:

- Maintain safety, integrity and performance of the network as its age increases whilst ensuring long term sustainability and supporting growth.

- Manage business risk through effective prioritisation of investment based on a methodical approach to asset criticality and risk assessment

Criticality assessment is used as part of our asset risk management process and defines the investment strategy and form of risk assessment that is applied to that asset.

This is summarised in Figure 3 where the relationship between criticality, risk assessment and investment strategy is outlined.

Asset Criticality	Risk Assessment	Investment Strategy
High	Subject to a detailed quantitative risk assessment.	Invest to prevent failure.
Medium	Subject to generic condition and performance assessment	Invest to prevent failure or achieve at least the national average failure rate depending on consequence of failure.
Low	Subject to generic performance monitoring and post failure inspection / condition assessment	Invest to achieve or maintain the national average failure rate depending on current failure level.

Figure 3

Transmission assets are generally classed as high or medium criticality assets the main exception being 132kV cables, which are classed as a low criticality asset. Our criticality assessment process classifies assets from high value down to detailed very small value assets.

As a result of the criticality assessment, the policy applied to the majority of transmission assets is to replace prior to failure. In this case "failure" is defined as when asset performance and reliability fall below acceptable operational limits and cannot be restored without an unacceptable financial risk and / or system risk exposure i.e. “It can’t be fixed”.

SPTL’s approach to Asset Risk Management has developed from practices in place on the distribution networks, enhanced the approaches and extended them to include transmission assets. This has ultimately led to the development of a robust expenditure forecast built on detailed condition information combined with asset modelling.

In general, a decision to replace an asset on the transmission network often represents a significant undertaking in terms of cost, environmental planning, acquisition of wayleaves / servitudes and outage management. Consequently asset replacement decisions have to be based on the best information available regarding current and future condition and performance. Age alone is not sufficient to form a judgement about asset condition.

Asset management priorities are expected to be consistent and cover two main areas namely:

- Ensuring high voltage apparatus complies with statutory legislation
- Asset modernisation driven by the greatest need in which network investment is directed on the basis of risk and criticality assessment taking account of factors such as public and staff safety, strategic importance, customer sensitivity to supply disturbances, asset performance and environmental considerations.

Our strategy for the management of transmission assets:

- Maximises the use of the remaining life while minimising the risk of unexpected failures
- Estimates the remaining life expectancy (“Remaining Useful Life”) of the asset population
- Selects and prioritises the order in which these assets should be replaced based on their known condition and on estimates of future rates of degradation, both of which optimise the annual rate of replacement
- Determines the scope and resources of a long-term replacement programme
- Takes environmental factors into account.

Our asset replacement policy ensures we:

- Do not routinely replace assets on a “like-for-like” basis,
- Consider each project on an individual basis taking into consideration wider factors such as,

    - Reinforcement requirements
    - Rationalising the existing network
    - Replacement with newer technology equipment to meet changing needs.

As explained previously, the criticality assessment process classes most transmission assets as high or medium criticality. In order to develop a fully prioritised replacement plan, this criticality classification is further refined. Each substation has been assessed for importance, taking account of customers, system security and connected generation to provide a relative importance ranking. The criticality process will be reviewed and enhanced to assess priorities and include other economic key points.

Circuit importance is then derived from the significance of the connecting substations and provides a relative importance of all circuits on the network. This information is used for the first stage in developing prioritised replacement plans for cables, overhead lines, transformers and switchgear.

The other factor in determining replacement priority is to consider asset condition. This is available from a variety of sources, ranging from routine inspection reports, to specific condition assessment programmes. An objective measure of the condition of each asset is considered together with the predicted consequences of failure to develop the final prioritised replacement plan.

3.0 IMPLEMENTATION

3.1 Network Asset Condition

It is SPTL's strategic objective to remove transmission assets from the network prior to failure and in some instances may be replaced early, as a result of load related work.

SPTL employ an approach which involves routine asset inspection that has been aligned with maintenance scheduling for both transmission and distribution activities and can be regarded as comprehensive and robust, especially as the data is captured centrally.

SPTL has extensive familiarity with most of the established condition assessment techniques relevant to the different asset categories that are used as inputs for asset replacement prioritisation.

Routine Asset Inspection and Maintenance Processes

SPTL has invested in IT systems to co-ordinate and track routine maintenance and inspection work. The routine inspection activity is strongly biased towards the site security and hazard detection rather than detailed asset condition assessment. The routine asset inspection activity ensures that SPTL comply with legislative requirements such as the Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002, as amended.

In order to improve efficiency, dedicated transmission trained staff record their inspection activities on a portable device capable of two-way communication with a central database and scheduling system. The device is of a compact design capable of data input (defects, security issues etc) directly onto the screen for onward transmission to SPTL's central systems in order that remedial action can be promptly scheduled.

An additional advantage of this system is the interface with SPTL's asset register and GIS system that enables staff to geographically identify particular assets from a map on the hand held device.

Hazard/defect rectification instructions captured within the asset inspection system are classified as follows:

Immediate: Potential access to live equipment. Staff must not leave site until rectified

Urgent: This is a hazard that requires urgent attention because there is either:

- A risk of unauthorised contact with live conductors, or
- The likelihood of a risk of danger resulting in injury arising within the next 3 months.

Programme: This is a defect that may either be,

- Of such a nature that it must be treated as a priority within this category and be cleared within a reasonable timescale to ensure it does not migrate into a hazard or introduce a risk to asset integrity, or
- Used to establish the condition of the electrical power system and would be cleared as part of a planned programme of refurbishment/ replacement.

When on-site, inspectors are prompted to follow pre-defined scripts to assess asset condition at a high-level for which input responses into the hand held device are required to complete the task. This approach to routine inspections, which had been aligned with maintenance scheduling for the transmission and distribution activities, can be regarded as comprehensive are robust, especially as the data is processed centrally and multiple systems are interfaced.

Detailed Asset Condition Assessment

Detailed asset condition assessment is essential for the prioritisation of non-load related capital expenditure, especially in the short-term. Such assessments are of critical importance to the capital planning process and Capex allowance discussions.

SPTL employ established condition assessment techniques relevant to the different asset categories.

Overhead Line Condition Assessment

For OHL's, SPTL adopt the following condition assessment techniques:

- High resolution, helicopter-mounted video imagined
- Infrared camera imaging
- Conductor CORMON Testing
- Foot Patrols
- Tower Climbing Assessments
- Foundation Surveys (specific assets as required)

SPTL have a prioritisation process for OHL refurbishment work which uses condition-based information as a key input.

Helicopter-borne Thermovision equipment is used to inspect steel lattice tower lines. Where practicable this is alternated with the safety inspection helicopter patrol. This inspection is used to identify high resistance conductor joints. Remedial work is categorised and programmed for completion in accordance with our hazard management policy described previously. Video records of the patrols are retained for a minimum period of one inspection cycle. In addition to the foot and helicopter patrols carried out for inspections, detailed condition assessments are undertaken on a periodic basis.

The network is condition assessed utilising airborne camera assessment technology (Schwem). The examination is used to check the integrity of the support structure and associated insulators and fittings.

Similarly, detailed conductor assessments, CORMON tests, provides information on conductor life expectancy, which is verified during examination of recovered conductor and earth wire.

The information provided by these examinations forms the basis of ranked work programmes for additional condition assessment, maintenance, tower painting or refurbishment.

Substation Condition Assessment

A variety of condition assessment techniques are employed by SPTL and full detailed assessments are undertaken as required. Specific substation condition related initiatives include:

- Assessment of building integrity
- Thermographic inspections
- Visual inspection of plant items

SPTL's approach to assessing the condition of switchgear is based on:

- Type (design and operational) issues
- Defects
- Operational checks (specific assets as required)
- Kelman timing checks (specific assets as required)
- Visual monitoring of corrosion
- On-line monitoring (specific assets)

SPTL, adopt an approach for switchgear based on asset families.

For **transformers and reactors**, the following additional conditional assessment techniques are employed:

- Dissolved gas analysis (DGA)
- Furfuraldehyde Analysis
- Moisture Content
- Acidity monitoring
- CO_2/CO monitoring

In addition to the information gathered during general and trespass / vandalism inspections, condition assessments including detailed inspections, operational checks, thermographic camera inspections to identify high resistance areas, and various oil and gas analysis condition assessments are undertaken on a periodic basis.

Oil and gas analysis tests are used to determine the condition of the plant and are used to predict the likelihood of certain types of faults before they occur within the tanks of transformers.

The information provided by the examinations form the basis of ranked work programmes for maintenance, refurbishment, plant painting or further condition assessment and testing.

Cable Condition Assessment

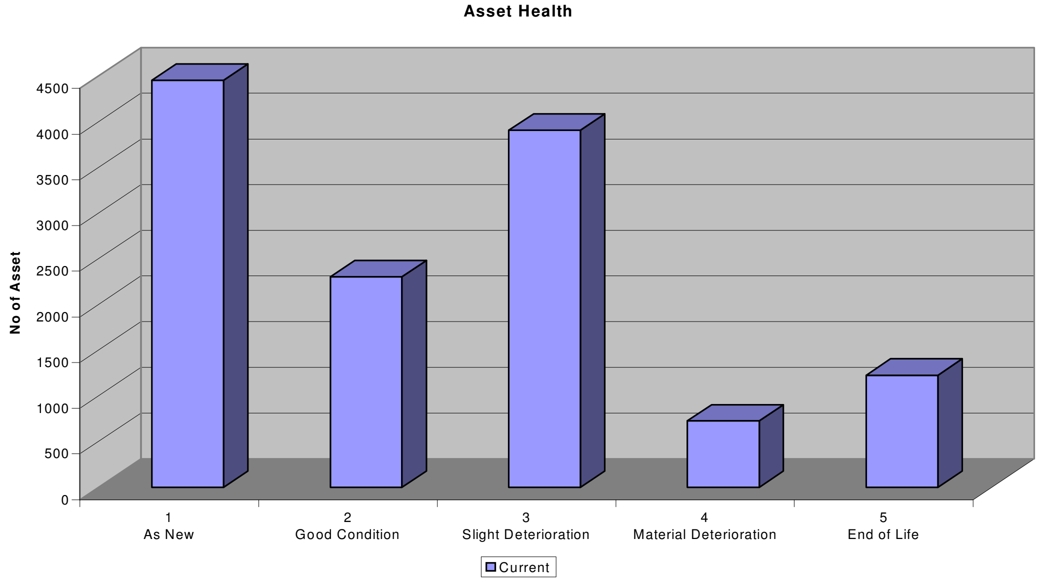
For cables, SPTL monitor the following parameters to assess asset condition:

- Failure history
- Gas and Oil leakage rates
- Termination visual inspections (specific assets as required)
- Chamber and tank corrosion (specific assets as required)

SPTLs familiarity with a wide range of condition assessment techniques is subsequently used as inputs to asset replacement prioritisation.

Condition Assessment Output

Based on the available condition information an asset health index is produced for the relevant asset category. The Asset health index assigns a relative health/condition value of between 1 and 5 to each asset dependant on the factors affecting its health. The number of assets in each specified category is then depicted graphically to demonstrate the overall health of the asset category as shown below.



An assessment of the length of time it takes for a typical asset to deteriorate between asset categories is made based on engineering knowledge of the criteria for each asset health category. This provides the rate of deterioration over the assets life and is directly linked to the average expected asset life. This provides the relationship between the asset health categories and the remaining useful life. For example a 275kV transformer has an average expected asset life of 55 years. The table below shows some example time periods to change categories for a typical transformer.

Health Index	Cat 1 to Cat 2	Cat 2 to Cat 3	Cat 3 to Cat 4	Cat 4 to Cat 5	Cat 5 to zero useful life	**Overall**
Time Period	20 years	15 years	10 years	5 Years	5 Years	**55 Years**

Based on these time periods the asset health categories can be directly related to the four remaining useful life categories. For the example above the relationship between asset health and remaining useful life is detailed in the table below.

Health Index	1 – As New	2 – Good Condition	3 – Slight Deterioration	4 – Material Deterioration	5 – End of Life	
Remaining Useful Life	> 10 Years			5 – 10 Years	2-5 Years	0-2 Years

3.2 Network Risk

Risk assessment and risk management is a vital component of SPTL's overall asset management strategy.

SPTL has adopted an asset criticality framework, which is a system level risk management technique with inputs relating to safety, legal, licence obligations, customer service, operations, faults and emergencies and costs. SPTL's Criticality Assessment Strategy sets out the approach adopted to classify the criticality of different network assets. As described earlier this approach assists with prioritisation of investment activities across asset categories.

SPTL has also adopted a concept of site criticality for substations in terms of customers, system security and levels of connected generation in order to determine relative 'importance'. The interconnecting OHL and cable circuits are then classified on a similar basis, taking account of the relative importance of the relevant substations. Combining this site criticality with asset health information provides an indication of network risk and allows replacement priorities to be identified.

Assessment of Site Criticality

Criticality is a representation of the impact to the UK consumer from a transmission system failure. Criticality is assessed in the areas of Safety, Environment and System criticality. The SPTL approach to site criticality has been developed over time and will continue to be refined through discussions with the other Transmission Licensees and internal review and implementation.

Safety Criticality

Safety criticality is based on the risk of direct harm to personnel, or the public, as a result of asset failure (e.g. conductor drop, fire or explosion). Safety criticality is scored as Very High, High, Medium or Low according to the matrix below which considers the impact of failure and the location of the asset.

		Location of Asset			
		Constant personnel/ public activity within vicinity of asset	High levels of personnel/ public activity within vicinity of asset	Regular personnel/ public activity within vicinity of asset	Limited personnel access. No likely public access
Impact of failure	Failure may result in fatality	Very High	Very High	High	Medium
	Failure may result in permanent incapacitating injury	Very High	High	Medium	Low
	Failure may result in reportable injury	High	Medium	Low	Low
	Failure results in minor or no consequence	Medium	Low	Low	Low

Environment Criticality

Environmental criticality is based on the environmental impact caused by asset failure. Environmental criticality is scored as High, Medium or Low according to the matrix below which considers the impact of failure and the sensitivity of the geographical area local to the asset.

		Location of asset	
		Asset located within proximity of environmentally sensitive area	Asset **not** located within proximity of environmentally sensitive area
Impact of failure	Failure may lead to reportable incident that may result in prosecution	High	Medium
	Failure may lead to significant incident with agency visibility	Medium	Low
	Failure may lead to minor incident that can be managed locally	Low	Low

System Criticality
System criticality is a measure of the impact of the transmission system not delivering services to the transmission Licensees customers or the smooth running of the UKs services and economy. System criticality is assessed in three main groups;

- Customers
- System security
- Generation

The factors contributing within the customers group are, the number of customers, the type of customer, public relation issues as a consequence of any customer loss, and the potential for the connection of future customers.

For the system security group the factors are, the site contribution to a Black Start, whether the site was part of the interconnected system, the group demand of the site, and how well the site could be fed from another location.

For the generation group the amount (MW) of generation connected was the only factor.

These groups and factors align with the high level areas indicated in the joint methodology of:

- Impact on vital infrastructure – addressed by customer type and PR factors in the customer group and by generation group.
- Impact on customers – addressed by customers group and generation group
- System security – addressed by system security group

For each site a score of between 0 and 3 is given for each factor. Details of the scoring are provided in appendix 1. An individual weighting is given to each factor to indicate its relative importance. The score for each factor is then multiplied by its weighting and then summed together to provide the overall system criticality score (0 to 3). The weightings for each factor are detailed below.

Group	Customers				System Security				Generation
Factor	Numbers	Type	PR	Future	Black start	Inter-connect	Group Demand	Alt Infeed	MW
Weight	8.7%	9%	7.7%	2.3%	11%	11.6%	7.7%	7.2%	34.8%

Based on the overall system criticality score the site is then assigned to a system criticality of high, medium or low, according to the following criteria.

Score	> 1.5	>0.5 & ≤1.5	≤0.5
Category	High	Medium	Low

Site Criticality
The site criticality is derived from the greatest impact identified from the three individual criticality scores. This ensures that the worst case impact is captured. The subcomponents of the criticality on a substation and circuit basis will be recorded and maintained. A sample format for this is provided in appendix B.

3.3 Network Performance

SPTL employ the Outage Planning Diary (OPD) to schedule and maintain outages, information from this tool is fed into a database, which can be accessed using the Business Objects reporting tool. A report will be run to find all outages within a specific time period, this information will then be filtered to remove outages that are not relevant to the reporting process (such as generator, telecoms and distribution outages). Outages that do not result in main circuit outages, such as bus coupler circuit breakers will also be removed. At this point any repeat outages will be examined and taken out, this accounts for the scheduling of several items of work on one circuit at the same time to minimise the amount of time that any circuit is out of service.

The remaining outages are then classified using various categories as described below:

- Type of Outage (Construction, Maintenance and Fault);
- Equipment Type;
- Whether the outage was booked within 24 hours (Unplanned Outages); &
- Reliability Outages (those that require repairs to be made to prevent equipment failure).

Each circuit has a corresponding number of circuit elements which are noted, these are defined as the overhead line, transformer or cable or any combination of these that connects two system bussing points together, or connects the system to a user's busbar. (A bussing point could be a substation or a tee point on the system). The time taken for each outage is then calculated and the unavailability found using the formula:

The sum for all circuit elements of hours unavailable x 100 %
(No. of circuit elements) x (No. of hours in period)

This figure can be calculated for all categories of outages, although it should be noted that unplanned unavailability will include elements of construction and maintenance in addition to faults due to the 'booked within 24hours' rule.

3.4 Network Capability

SPTL currently report on transmission system capability as part of the Transmission Regulatory Reporting Pack. It is intended that the capability sections from Table 4.8 “Boundary Transfers and Capability” will be used to meet the requirements of the Licence Condition. This will provide a measure of the existing and future transmission capacity being provided by the Transmission Operators on the main interconnected transmission system.

3.5 Network Utilisation

The Transmission Regulatory Reporting Pack requires the SPTL “to collect information relating to more localised demand driven need for developing transmission infrastructure”. This is presented in Table 4.9 “Demand and Supply Capacity at Substations” with Utilisation being represented as demand as a percentage of capacity. This will show the relationship between localised demand and capacity and hence provide a proxy measure for utilisation.

Appendix A – System Criticality Scoring

Customers	
Numbers	0 - zero connected customers
	1 – 0 to 20,000 connected customers
	2 – 20,000 to 35,000 connected customers
	3 – 35,000 + connected customers
Type	1 – Domestic
	2 – Industrial
	3 – Site supplies customers identified in section 9 of the emergency planning manual
PR	0 – No effect
	1 – Requires Operations statement
	2 – Requires PowerSystems statement
	3 – Requires Corporate Communications statement
Future	0
System Security	
Black Start	0 – No contribution
	1 – Synchronising e.g. Neilston 132
	2 – On secondary Black Start route e.g. Galloway Hydros
	3 – On main Black Start route
System i/c	0 – None
	1 – 132kV active network
	2 – Galloway 132kV system and non "Figure 8" sites
	3 – Central Scotland "Figure 8" sites
Group demand	0 – Less than 12MVA
	1 – 12MVA to 60MVA
	2 – 60MVA to 300MVA
	3 – greater than 300MVA
Alt. Infeeds	0 – Less than 100%
	1 – 80% to 100%
	2 – 30% to 80%
	3 – Less than 30%
Generation	
MW Connected	0 – Less than 5MW
	1 – 5MW to 50MW
	2 – 51MW to 999MW
	3 – greater than 1000MW

Appendix B –Criticality Subcomponents Table

Ref	Substation/ Circuit	Voltage	System											Safety			Environment		
			Customers				System Security				Genration	System Criticality score	System Criticality						
			Numbers	Type	PR	Future	Black start	System I/c	Group demand	Infeeds	MW Connected			Impact	Location	Criticality	Impact	Location	Criticality
1	A	275	1	2	2	0	0	2	3	0	2	1.58	High	3	2	Medium	2	2	Medium
2	B	275	2	3	2	0	0	0	2	1	1	1.17	Medium	4	3	Very High	1	3	Medium
3	C	132	2	3	2	0	1	0	2	0	0	0.86	Medium	1	4	Medium	1	1	Low