Network Development Plan 2022

Methodology Report

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Disclaimer

Contents

This document outlines the methods used in the Network Development Plan (NDP). Further background information can be found in the NDP Introduction and Purpose document published on the WPD website.

Network Analysis Approach

The NDP aims to identify areas of the distribution network where investment may be required to alleviate a constraint. This section outlines the approach taken to identify network constraints and the input data and tools used.

Input Data

In order to undertake detailed electrical analysis of any electricity distribution network the four components detailed in the matrix in Table 1 are required. It is important to ensure all four areas of this matrix are included within any analysis to maximise the value and accuracy of the output. Each of these sections are discussed in detail below.

Table 1: Summary of the aspects required for detailed electrical analysis of the distribution network.

	Network	Customers
Assets	Network topology and connectivity information, including impedance and 'nuts and bolts' data about the assets connected to the WPD network. Normally this is captured in a network model in power system analysis software.	Customers connected to the distribution network, including the type of demand or generation connected. This also includes information on the machines or assets that customers have connected to the network (such as Electric Vehicles or Heat Pumps).
Behaviour	Actions taken by the DNO to actively manage the network. This can be in the form of updated running arrangements once an arranged outage is taken, or load management schemes in place to manage network flows. This information is vital if contingency analysis is required.	Expected behaviour of customers connected to the distribution network, with reference to the focus and purpose of the network analysis to be undertaken.

Customer Assets: DFES Volume Projections

The Distribution Future Energy Scenarios (DFES) provide granular scenario projections for the growth (or reduction) of generation, demand and storage technologies which are expected to connect to the Great Britain (GB) electricity distribution networks. The Western Power Distribution (WPD) DFES also includes projections for new housing growth and increase in commercial and industrial developments. The projections are also informed by stakeholder engagement to understand the needs and plans of local authorities and other stakeholders.

The development of DFES has enabled WPD to take a more proactive approach to network planning. Stakeholders were consulted via a series of consultation events, as well as direct engagement with local authority planners and climate emergency officers. WPD publishes the DFES volume data as part of a suite of documents, projections are also displayed as part of an interactive map on the WPD website.

Customer Behaviour: DFES Behaviour Assumptions

The next step in the DFES process is to account for customer behaviour to the projected volumes. This is used to take into consideration the expected demand and generation profiles of new and existing customers connected to the distribution network. This includes assumptions for how customers connected to the distribution network will change over time due to an increase in energy efficiency and pricing-led Demand Side Response (DSR). When the customer behaviour assumptions in this document are applied to the DFES projections a load set of MW/MVAr values can be generated. The NDP uses the latest published Long Term Development Statement (LTDS) Table 3 data for the starting load assumptions.

Further information on the customer behaviour assumptions is available as part of the DFES: Customer Behaviour Assumptions Report.

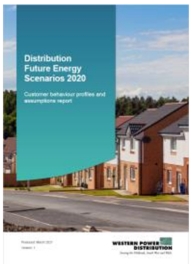

Figure 1: DFES Customer Behaviour Assumptions report for the 2021 edition of the DFES projections.

Network Assets: Extra High Voltage Power System Models

Network Assets are modelled through the extra high voltage (EHV) network models maintained by WPD. The same information is published annually as part of the LTDS, to allow third parties to model the distribution network, but models are constantly updated as assets are replaced and new connections made to the distribution network. The network model must also include the appropriate ratings of network components, accounting for seasonal factors and any cyclic capabilities.

A snapshot of WPD's EHV models was taken on 21st January 2022 and these models were used to model the forecast demand sets from DFES. For each year into the future, the models were amended to ensure that future connections were incorporated into the model in the correct year and thus the demand be accurately distributed across the assets. As part of the transition to a common power system analysis software package across WPD, the network models for the East and West Midlands used in this NDP are derived from the model published in the November 2021 LTDS.

Network Behaviour: Automation and Manual Switching Schemes

In order to accurately identify the point where an investment decision is required, the effects of network automation and manual switching schemes should be included in analysis. If these actions are not modelled, the results may not be representative of how the network would react to specific outages. This could include the behaviour of network automation and manual switching schemes including:

- auto-close schemes;
- intertripping;
- directional overcurrent schemes;
- overload protection;
- sequential control (SQC); and
- load transfers.

Assessment Periods

Traditionally, distribution networks are assessed using 'edge-case' modelling, where only the network condition that is deemed most onerous is analysed. As the installed capacity and behaviour of demand, generation and storage is rapidly changing, it has become difficult to predict what network condition will be most onerous.

To cover a range of likely onerous cases, WPD consider a range of different potential representative days, which are used to assess network capability, as outlined in Table 2. The definition of seasons is taken from Engineering Recommendation P27/2 (Current rating guide for high voltage overhead lines operating in the GB distribution system):

- **Winter**: January, February and December
- **Intermediate Cool**: March, April and November
- **Intermediate Warm**: May, September and October
- **Summer**: June, July and August

Table 2: Representative Day descriptions used for analysis within the Network Development Plan.

	Demand Headroom Assessment	Generation Headroom Assessment
Representative Day	• Winter Peak Demand • Summer Peak Demand • Intermediate Warm Peak Demand	• Summer Peak Generation
Justification	The peak demand is assessed with minimum coincident generation. Coverage of all seasons allows for an assessment of the network's capability to meet not only annual peak demand conditions but also the demand conditions during periods of planned maintenance on the network.	The peak generation representative day is assessed with minimum coincident demand. This aims to provide an assessment of the network's capability to handle generation output. The season where generation constraints most normally occur is during summer, with relatively low demand and high output of renewable generation.

The expected peak network loading under different seasons can be compared against the seasonal rating of assets. The demand profile for many areas of the network show that although the peak demand may often appear in the cooler months, the reduction of the network's asset ratings in the subsequent warmer seasons can be greater than the corresponding reduction in demand.

Constraint Identification

The distribution network is designed to comply with a number of electricity engineering standards and policies, as listed in the sections below. If steady state load flow analysis identifies a deficiency in the network for any one of the assessment criteria below, an investment decision is required.

It is worth noting that strategic planning is not the only method of identifying load related investment on the distribution network. Constraints identified as part of new connections planning and condition based asset replacement programmes can also affect investment decisions. These are appraised as part of the Distribution Network Options Assessment (DNOA).

Contingency analysis

Contingency analysis is the analysis of the network under abnormal conditions to confirm that the network complies with Engineering Recommendation P2/7, which outlines the minimum standards for the demand security of supply that must be provided to customers. Any security assessment should accurately cover the assessment process in Section 4 of Engineering Report 130, which provides guidance on the application of Engineering Recommendation P2/7. The demand and generation capacity of a network is not normally limited by its characteristics under normal running conditions, but by its characteristics under abnormal running conditions. There are two broad classes of network outage:

- **Fault outages:** when a component of the network fails, it is detected by protection relays, which open the circuit breakers enclosing the failed component. This de-energises the network between those circuit breakers, so clearing the fault. By their nature, fault outages cannot be predicted so may be expected to happen at any time;
- **Arranged outages:** each component of the network needs to be accessed for periodic or condition-driven inspection, maintenance and replacement. Similarly, access may be required for reinforcement or to make new connections. The minimum zone to access any particular component is usually defined by the isolators enclosing the component. The scheduling of arranged outages is flexible to some extent, so can take advantage of seasonal variation in network loading.

Since any component of the network could fail, it is necessary to assess the impact of each credible fault outage on the network. Since each component of the network will need to be accessed eventually, it is necessary to assess the impact of each credible arranged outage on the network. These are both types of First Circuit Outage (FCO). When combining these two requirements, it is also possible that a network component could fail during access to another network component. It is therefore also necessary to assess the impact of each credible fault outage during each credible arranged outage. Each combination is a Second Circuit Outage (SCO).

To undertake contingency analysis, a network model that can accurately replicate outage conditions is required. This includes circuit breakers and isolators, to determine protective and isolatable zones respectively. The following outage types and combinations of outage types should be studied on the distribution networks (and associated transmission networks if necessary):

- the intact (normal running) network;
- each circuit fault;
- each busbar fault;
- each arranged circuit outage;
- each arranged circuit outage followed by each circuit fault;
- each arranged busbar outage;
- each arranged busbar outage followed by each circuit fault.

Power systems analysis is necessary to accurately quantify the intrinsic network capacity and transfer capacity available of a network, particularly for networks operating with complex configurations. Some of the EHV networks in WPD licence areas have complex running arrangements which necessitate multiple contingencies to be studied in different areas to capture the worst case outage combination.

Network Integrity

The definition of network integrity is defined as the ability of a network to operate within thermal, voltage and other technical limits, excluding frequency-related limits, under both intact network and outage conditions. The technical limits covered by the NDP analysis are discussed below, more information on the limits with which WPD operates its network can be found in the following documents published by WPD:

- Policy Document: SD4/9 (Relating to 11 kV and 6.6 kV Network Design).
- Policy Document: SD3/9 (Relating to 66 kV and 33 kV Network Design).
- Policy Document: SD2/8 (Relating to 132 kV Network Design).

It is worth noting that for network integrity analysis, WPD cover secured outage conditions in excess of those identified in Engineering Recommendation P2/7, such as busbar fault outages and arranged outages followed by busbar fault outages. By increasing the level of detail being analysed and analysing these busbar fault conditions, network integrity for thermal and voltage constraints is fully assessed for credible outage combinations.

Thermal assessment

In addition to security assessments, comprehensive network analysis can highlight assets that could operate outside of their technical limitations. Depending on the network running arrangements, a network could comply with the demand security of supply standard requirements, but still result in overloaded assets under different outage combinations. At this point, an investment decision must be made by the DNO to do one of the following:

- Reinforce overloaded assets to alleviate the network constraint. Note this could also encompass wider strategic works rather than uprating overloaded assets;
- Load management schemes to manage network loading and voltages by either controlling demand and/or generation connected to the network, operating switchgear to change the topology of the network and/or controlling the settings of tap-change controllers, reactive compensation equipment and flexible power links;
- Operational mitigation to reduce the risk of overloads occurring, which could include limiting the window where arranged outages can be taken.
- Procure flexibility services from customers (where technically appropriate to do so) to reduce network asset loading.

Studying multiple seasons is important for the thermal loading assessment to highlight the season where an overload is most likely to occur, as operational mitigating measures or flexibility services could be utilised to defer conventional reinforcement.

Voltage assessment

The Electricity Safety, Quality and Continuity Regulations (2002) define the limits on voltage which distribution network operators can supply to customers. These are dependent on the voltage level and provide a bandwidth for which the voltage at customer terminals must stay within. These limits influence the design of voltage control on all levels of distribution networks and must be accounted for when identifying strategic developments.

Network analysis should identify any voltage exceedances outside of statutory limits for intact network conditions and all secured outage conditions. Solutions to mitigate any voltage exceedances could include reactive power compensation or network reconfiguration, in addition to reactive power services provided by customers.

System Integrity

System integrity is the ability of the GB system to operate within acceptable frequency-related technical limits under both intact network and outage conditions. System integrity is primarily managed by National Grid, but it can be affected by the operation of WPD's network and customers. This could include a change of load across all WPD licence areas greater than 300 MW, which could result in system integrity issues on the electricity system.

No power system stability studies have been carried out for the NDP; however, constraints highlighted that impact the transmission/distribution boundary are an indication that further whole system studies are required with the GB System Operator and Transmission Network Operators. If necessary, these will be progressed through Regional Development Programmes (RDPs).

Fault Level

Calculation of fault levels should be carried out in accordance with Engineering Recommendation G74/2, which was introduced in July 2021 with a year period for networks to implement. Switchgear stressing assessment is required as it can form a large part of strategic investment planning decisions, as the impacts of fault level studies can limit running arrangements on distribution and transmission networks.

Complexity of Circuits

Engineering Recommendation P18 relates to the complexity of 132 kV circuits, this assessment is carried out for intact network conditions only. WPD also applies the complexity of 132 kV circuits to 33 kV and 66 kV networks.

Other relevant network design standards

In addition to network security, integrity and voltage studies on a network, there are additional standards that DNOs must follow when designing networks. These are outlined below, but are currently outside the scope of the NDP, which are considered for specific customer connections so are covered by the existing connection planning process:

- Voltage unbalance as defined in Engineering Recommendation ER P29/1.
- Voltage fluctuations as defined in Engineering Recommendation ER P28/2.
- Harmonic limits as defined in Engineering Recommendation G5/5.

Balance between detailed and simplified analysis

Comprehensive electrical analysis is required to accurately identify network constraints and suggest solutions. Developments in the automation of power system analysis tools means that this analysis is becoming more feasible, quick and inexpensive. Comprehensive analysis techniques require manual interrogation of results by power system engineers, and modelling of network interventions to enable model convergence in longer-term studies.

However, accounting for the number of outage combinations and representative day inputs that are required for the analysis outlined above results in approximately 3.5 billion individual load flow studies for each scenario and year combination for all WPD EHV networks. With the projected growth in demand and generation connected to distribution networks in years approaching 2050, a large amount of network interventions are required to ensure the steady state load flow analysis can calculate valid results (i.e. the load flow is able to converge).

As a result, DNOs must choose between different approaches to satisfy the licence conditions in the NDP. For the different component reports in the NDP, WPD run two processes in parallel to produce the most accurate network analysis results. This is summarised in Table 3, and explained in the following sections of this report.

Table 3: Summary of network analysis methodologies.

Component	Network Headroom Report	Network Development Report
Input	DFES 2021 for starting load assumptions and forecast projections. EHV Network Models for asset data, as reported in LTDS.	DFES 2021 for starting load assumptions and forecast projections. EHV Network Models for asset data, automation and manual switching schemes modelled.
Analysis Type	Comparison of demand/generation and firm capacity as defined in Ofgem RIIO-ED1 Regulatory Information and Guidelines.	Load flow contingency analysis of all outage combinations and reporting of thermal, voltage and demand security constraints.
Network coverage	Whole network.	Targeted areas where network development required.
Benefits	Allows for coverage of all substations within the WPD extra high voltage networks for a period out to 2050, and is quick and simple to produce.	Accurate constraint identification that aligns to DNO investment planning and operational processes, remedial solutions can be modelled to check suitability.
Disadvantages	Not comprehensive enough to accurately identify the point where an investment decision is required.	Computationally expensive, requires automated tools to undertake network analysis.
Justification	Suitable as an indication of likely network constraints in future years out to 2050.	Detailed analysis required to justify investment decisions made.

Network Headroom Report Methodology

This section outlines the analysis methodology used to obtain the network headroom figures contained in the Network Headroom Report. This builds on the Network Headroom Report published in 2021 for stakeholder consultation on the format. On the WPD website, a workbook for each licence area contains the network headroom for both additional demand and generation connections across the four DFES scenarios as well as the WPD Best View. These are included for all years out to 2050. The methodology for both demand and generation headroom is discussed separately below.

Constraint Identification

Demand Headroom Calculation

To assess the current and future available capacity and to identify constraints that require intervention during the DFES time horizon, scenario growth data was compared against the firm capacities for each Primary substation and Bulk Supply Point (BSP), whereby:

- A Primary substation refers to a substation where the low voltage side of the voltage transformation is either 11 kV or 6.6 kV. This is consistent with the definition of the Electricity Supply Areas used in the DFES studies. Note that this encompasses sites with 132/11 kV transformation, which are also sometimes referred to as Bulk Supply Points;
- A Bulk Supply Point refers to a substation where the high voltage side of the voltage transformation is 132 kV and the low voltage side of the voltage transformation is either 33 kV or 66 kV.

The firm capacities are consistent with those published in Table 3 of the LTDS and on the Network Capacity Map application. Growth rates were calculated at a Primary substation level, so to produce suitable projections at a BSP level the average growth rates of the Primaries downstream from each BSP were applied to the max demands in 2020/21 from the LTDS. This approach helps account for diversity and should produce more accurate projections than simply summating the Primary demand sets. The headroom available at the upstream BSP can be used to infer if there is a potential constraint on the upstream network that could affect the capacity for connections at lower voltage levels.

Generation Headroom Calculation

For the Network Headroom Report, generation headroom is also included as it is acknowledged that the NDP must meet the needs of different stakeholders interested in both generation and demand connection capacity. The calculation for the generation headroom consists of two parts, each discussed below.

Thermal headroom

For the Summer Peak Generation representative day, the net loading at each Primary substation and BSP is calculated by subtracting the maximum credible coincident generation output from the expected demand profile each half hour. The half hour where the net loading was minimum is identified as the edge-case required for generation headroom analysis. It is worth noting that this does not necessarily correlate to the half hour of maximum generation output, nor to the half hour of minimum demand. It is particularly important to understand the generation technologies connected within an area to appropriately forecast the worst case network conditions for generation headroom assessment.

The net loading for each Primary substation is compared against the reverse power flow ratings consistent with those used in the WPD Network Capacity Map to calculate the generation headroom. The reverse power flow headrooms are calculated from the LTDS where available, and assumed to be 50% of the firm capacity rating where unavailable in the LTDS. A negative headroom does not necessarily result in a network constraint, as through alternative connection offers and load management schemes such as Active Network Management (ANM), some customers can be constrained for certain outage conditions to ensure no overloading of assets occurs.

Fault level headroom

Consideration of fault level is included because it is a major constraint on generation connections. For the Network Headroom Report, an initial fault level assessment is undertaken. The existing maximum prospective fault levels under normal system running conditions and the make and break switchgear ratings at bussing points are taken from the LTDS Table 4, which is consistent with the Network Capacity Map.

The additional generation expected to connect at each Primary substation for each year, scenario and generator type is calculated using an expected fault infeed contribution consistent with the figures published in the Western Power Distribution Policy Document: SD7F/2. This is added onto the existing maximum fault level and compared to the switchgear make and break ratings to calculate a fault level headroom in kA.

In order to provide a single figure for the generation headroom, the fault level headroom in kA is converted to an equivalent assumed power figure of generation to connect to the network. This uses an assumed weighted average for the make and break fault infeed contribution of all projected generation to connect across the DFES horizon. The minimum of the thermal and fault level MW headroom is then chosen as the generation headroom for any given year, scenario and Primary substation.

Modelling limitations

General

1. The impacts of planned reinforcements, contracted flexibility and load management schemes are not included in the Network Headroom Report. For certain outage conditions load management schemes may operate to constrain customers to ensure no overloading of assets occurs. Comprehensive power systems analysis is required to model the impacts of load management schemes.
2. In the Network Headroom Report, when a potential network constraint is identified no reinforcement is modelled to alleviate the network constraint. Comprehensive power systems analysis requires network interventions to be modelled in order to enable model convergence in future years – these are modelled for the areas considered in the Network Development Reports.
3. To enable accurate analysis on the distribution network, a representative Transmission model is necessary. This Transmission representation is an equivalent of the full Transmission network and, when incorporated into the WPD power system model, approximates the network behaviour. This data is provided by National Grid as part of the Week 42 data exchange. The size of the equivalent model varies for each licence area, depending on the level of Grid Supply Point (GSP) parallel running and interconnection. Currently transmission models are not provided for future years, scenarios and seasons, which could increase the accuracy of future headroom modelling.

Thermal headroom analysis

4. For both demand and generation network headroom assessments, a firm capacity style analysis may not fully capture the complex nature in which distribution networks are run. Where areas of the distribution network run interconnected, each distinct area cannot be studied in isolation the network loading is susceptible to changes in other parts of the parallel group. Comprehensive power systems analysis is required to fully capture the available headroom for the distribution network.
5. A firm capacity style analysis may define the headroom available to connect demand or generation at a particular voltage level, however this may not capture the available headroom at upstream voltage of the distribution network, which may be the limiting factor to connect new demand and generation. Again, comprehensive power systems analysis is required to fully account for the materiality headroom for different parts of the distribution network.

Fault level analysis

6. The fault level analysis only considers the additional fault infeed from generation connected at each Primary substation in isolation. It does not account for wider network changes that would affect upstream fault infeed due to the connection of additional distributed generation (DG), removal of generation (particularly synchronous plant) and changes in network topology. To assess changing fault level accurately detailed power system analysis is required, with a future National Grid equivalent model representing the appropriate year, scenario and loading condition.
7. Only three phase faults were considered in the initial fault level analysis for generation headroom assessment.
8. Fault level assessment assumes that new demand and generation would connect directly to the 11 kV or 6.6 kV bar of the Primary substation. As a result, this is a worst-case assumption as no additional impedance assumptions have been made for the connection of new demand and generation.

Network Development Report Methodology

This section outlines the analysis methodology used in the Network Development Reports, which contains the results of comprehensive power systems analysis that has been carried out on areas of the network where developments are required. This analysis was performed using the four DFES scenarios as well as the WPD Best View and each section of network is assessed across the next 10 years.

Areas where network developments are likely to be required in the 0-10 year window were identified from existing analysis undertaken for the RIIO-ED2 business plan, also from study of the baseline year across different parts of the WPD network. Each area of network where an investment decision is required in the 0-10 year window is reported as a series of short technical reports. These will provide the justification of the required investment to stakeholders through robust evidence and technical detail.

Throughout RIIO-ED1 WPD has developed a tool for automated analysis of EHV distribution networks, aligning to the comprehensive electrical analysis as outlined in the Network Analysis Approach section of this report. The Switch-Level Analyser tool is a bespoke power system analysis program written in Python 2.7. It uses PSS/E version 34 as its core analysis engine to perform the actual load-flow calculations, and uses some of PSS/E's built-in contingency analysis tools for efficiency.

All input data for studies are stored on a centralised server-side database. The following inputs are combined for each half hour, representative day, year and scenario studied:

- Network model, including network changes made relative to the year studied;
- Load set mapped to the boundary nodes of the network model (aligned to the definition of an Electricity Supply Area used in the DFES studies). This also includes half-hourly profiles for each type of demand, generation and storage and representative day;
- Appropriate ratings of network components; and
- Existing network automation and manual switching schemes.

These results are processed within the program and exported to a results database, which are summarised in tabular and graphical formats for further evaluation by skilled power systems engineers. Whilst this approach can be seen as computationally expensive, a distributed computing approach is used to improve runtime efficiency.

Constraint Identification

Outage Modelling

To assess the current and future constraints that require intervention during the 0-10 year horizon, all outage combinations are studied using the Switch-Level Analyser tool. Each study is broken into a specific year, scenario, half hour and representative day for a focused area of network. Where areas of the distribution network run interconnected, the network is studied as a whole to account for changes in other parts of the parallel group and fully capture the constraints for the distribution network.

For each half hour, day, year and scenario studied, the program returns the following for all outage combinations modelled:

- MVA flow on all branches of interest;
- Voltage exceedances for all nodes of interest;
- Lost load (i.e. demand disconnected) for all groups;

- Group load (i.e. the demand and generation of each GSP, BSP and Primary substation group) for all networks; and
- Any studies where the program was unable to calculate valid results (non-convergences).

Modelling Network Automation and Manual Switching Schemes

The demand and generation capacity of a network is not normally limited by its characteristics under normal running conditions, but by its characteristics under abnormal running conditions. Abnormal running arrangements occur due to faults, maintenance, network construction and other reasons. The Switch-Level Analyser tool uses the PSS/E Advanced Contingency and Remedial Action Scheme (RAS) add-on module. This module takes user-defined conditions and performs an action dependent on the outcome of the condition. WPD has used this module to model the behaviour of network automation and manual switching schemes as outlined in the *Network Behaviour: Automation and Manual Switching Schemes* section of this report. The modelling of schemes is agreed and confirmed with WPD Primary System Design and Outage Planning Teams. Details on specific Remedial Action Schemes modelled are included in each of the individual Network Development Reports as part of the NDP publication.

Network reconfiguration

Under outage conditions, the topology of the EHV distribution network can be altered, either by WPD Control Engineers or by network automation. This can be to ensure network compliance is maintained, to reduce the risk of overloading assets for a credible next fault or to limit the Customer Interruptions (CIs) and Customer Minutes Lost (CMLs) for a credible next fault.

As each outage combination is simulated on the network model, the Switch-Level Analyser checks the status of isolators and circuit breakers across the monitored contingency area. If the user-defined condition statement returns true, a subsequent switching action is taken as would be by the WPD Control Engineer or network automation scheme.

Load Management Schemes

A Load Management Scheme is defined as plant, equipment and software systems that together manage network loading and voltages by either controlling demand and/or generation connected to the network, operating switchgear to change the topology of the network and/or controlling the settings of tap-change controllers, reactive compensation equipment and flexible power links.

Load Management Schemes are modelled to account for the following:

- Protection style intertrip schemes to automatically disconnect parts of network for a certain network condition;
- Auto-changeover and auto-close schemes, such as to switch in a transformer run on hot standby under fault outage conditions;
- Overload protection schemes to open circuit breakers when a current limit is exceeded on a monitored branch.

Active Network Management is also included as a Load Management Scheme. The existing analysis tools do not replicate the ANM logic, which requires iterative load flows to control generation or demand according to the Last In First Out (LIFO) stack of connected customers. The behaviour for customers with existing ANM contracts is modelled to validate the behaviour of existing systems.

Flexibility Services

Flexibility services can be used to reduce network loading for a given condition through network users in their own consumption by increasing, reducing or shifting their net import or export during peak loading periods. The analysis takes into account existed contracted flexibility which can be relied upon for security and network integrity assessments, and this is included in the models to validate that the procured services can alleviate the network constraint.

In future years, the flexibility services required to alleviate a network constraint identified can be quantified by reducing the loading on any constrained circuit. The location of any flexibility services procured has a sensitivity to a given constraint, which must be factored into the decision for procurement of services.

Constraint Alleviation

Upon the identification of a constraint, solutions can be modelled and assessed for suitability to alleviate the network constraints. Each of the following remedial solutions are considered and modelled for their impact on the network studied and adjacent/interconnected networks.

- **Conventional reinforcement** - for example replacing overloaded assets with increased ratings;
- **Strategic reinforcement –** where multiple constraints are identified in the same area of network, a more cost effective solution could be to establish new substations to increase the capacity of the group. This can help with network security assessments by ensuring the group demand remains within the existing P2 Class of Supply;
- **Operational mitigation –** actions taken by WPD to alter how assets are maintained and operated. Examples could include limiting when arranged outages can be taken on the network to reduce the risk of any subsequent credible next fault overloading network assets;
- **Load Management Schemes –** installation of network automation to manage network loading for given conditions through control of demand and/or generation through operational measures, as part of existing customer connection agreements. This could include modelling of additional load on the network connected to an Active Network Management scheme;
- **Flexibility Services –** procurement of services from customers connected within the area of network studied to reduce loading on network assets under different conditions. Services will be procured through commercial contract arrangements. This can be quantified using the detailed network analysis, but commercial analysis is required to ascertain if services are available to procure that is outside the scope of the NDP.

A key aspect of the comprehensive network analysis is the ability to model the solution options to ensure that any solution is fit for purpose in future years in the 0-10 year horizon as covered by the NDP. For network build solutions, these are also checked against expected growths to reduce asset stranding risks out to 2050.

Once the solution options are confirmed for a constraint, costs for each option are generated along with likely timescales. The options are then appraised as part of the DNOA, which uses a Cost Benefit Analysis methodology to justify the near-term investment decision made.

Benefits over firm capacity style analysis

The comprehensive approach to network analysis used for the Network Development Reports has the following advantages over the analysis used for the Network Headroom Report.

- The impacts of planned reinforcements, contracted flexibility and load management schemes are included. Under outage conditions, load management schemes may operate to constrain customers to ensure no overloading of assets occurs. The impacts of these actions.
- Using power systems analysis tools can be used to accurately quantify problems on interconnected networks. An example of this is the available transfer capacity to an adjacent network, which may be required for network compliance. This transfer capacity is dependent not only on the interconnecting circuit capacity, but also on the available capacity of the adjacent demand group to accept load transfers. This assessment cannot be made without detailed electrical analysis.
- Available headroom at upstream voltage of the distribution network, which may be the limiting factor to connect new demand and generation, is modelled and the materiality headroom for different parts of the distribution network fully captured. This better aligns with the existing connections planning process run by networks.

Modelling limitations

1. To enable accurate analysis of the distribution network, a representative Transmission model is necessary. This Transmission representation is an equivalent of the full Transmission network and, when incorporated into the WPD power system model, approximates the network behaviour. This data is provided by National Grid as part of the Week 42 data exchange. The size of the equivalent model varies for each licence area, depending on the level of GSP parallel running and interconnection. Currently Transmission models are not provided for future years, scenarios and seasons, which could increase the accuracy of future headroom modelling.
2. Only load-flows assessing steady-state voltage and power flows have been undertaken. No power quality, protection or stability studies have been carried out.
3. The Switch-Level Analyser tool does not model fault level analysis or switchgear stressing studies. This is currently modelled separately but is planned to be fully integrated into the Switch-Level Analyser tool in future.

Future Developments

The approach to investment planning ensures that WPD has a transparent framework for identifying and selecting the optimal investment plan. The distribution network continues to become more complex and active due to the decentralisation of the generation mix across the UK and more opportunities for customers to alter energy consumption and participate in flexibility markets. As a result, the analysis tools and techniques required for network impact assessment also require development. This is to ensure that the network impact assessment captures the most onerous network loading conditions, essential to the coordinated, economic and efficient design of the network.

WPD's strategic vision is to continue to develop our capability to undertake forecasting and network impact assessment. For forecasting activities, this includes incorporating improved techniques to better understand the composition and coincidence of demand and generation customers to more accurately study the credible onerous network loading conditions. For network impact assessment activities, this includes further automating analysis tools and techniques to more comprehensively study our networks.

The areas for further development in the NDP are listed below:

- An updated model of the transmission network for future years, scenarios and times of year would help to increase the accuracy of power systems analysis results. Additional data exchange requirements between transmission and distribution networks is currently being explored as part of Grid Code modification GC0139. WPD will continue to look to improve the network model data at the transmission and distribution boundary.
- The WPD network supplies areas that run in parallel with other distribution networks. For accurate identification of future constraints, the future growth of interconnected networks operated by other DNOs needs to be modelled. Where network constraints are identified on an interconnected network, this could be progressed through RDPs.
- Improve the technical capabilities of the existing Switch-Level Analyser tool to cover switchgear stressing studies, voltage unbalance and voltage fluctuation studies. This will align the strategic planning process with the existing connections planning process run by DNOs.
- Increase the scope of the NDP analysis to cover High Voltage (HV) networks. This requires automated tools as the complexity and size of HV networks is significantly larger than EHV networks.
- Better capture the short to medium-term ambitions of major energy users to incorporate the planned usage of reserved capacity and ensure we can maintain an economic and efficient network in our planning process.

Please contact wpdnetworkstrategy@westernpower.co.uk to provide any additional feedback on the content of the NDP.

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