Customer-Led Network Revolution

NPADDS Enduring Specification

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Summary

The Customer-Led Network Revolution (CLNR) project has developed an innovative prototype software tool to aid distribution network planners and designers in the move to low carbon networks. The software is called the Network Planning and Design Decision Support (NPADDS) tool.

A full description of the functionality and inner workings of the prototype tool is available in a separate document, entitled *NPADDS Prototype Functionality and Benefits Case[1]*, available in the CLNR online project library. The tool that was developed is a prototype and as such further work is required to make it a 'production quality' tool. This document describes the further work needed to implement in a Business As Usual (BAU) context.

This document provides a specification for an enduring software tool that would represent a significant upgrade to all GB DNOs' software tools used for planning and design purposes. It is noted that many functions specified are not commercially available and require innovative investment to develop them further and would need to be aligned to DNOs' needs. The specification can therefore be used to assist procurement, but not directly at this stage. The specification highlights the areas that require further innovation.

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[1] CLNR-L255: NPADDS Prototype Functionality and Benefits Case. Available on the CLNR website project library; http://www.networkrevolution.co.uk/resources/project-library/

Glossary

AVC	Automatic Voltage Control
BAU	Business As Usual
CIM	Common Information Model
CLNR	Customer-Led Network Revolution
DNO	Distribution Network Operator
DSR	Demand Side Response
EES	Electrical Energy Storage
EHV	Extra High Voltage
EV	Electric Vehicle
GUS	Grand Unified Scheme
HP	Heat Pump
HV	High Voltage
LCT	Low Carbon Technology
LDC	Line Drop Compensation
LV	Low Voltage
MW	Megawatt
NPADDS	Network Planning Design and Decision Support tool
NRC	Negative Reactance Compounding
OLTC	On-Load Tap Changer
PC	Personal Computer
PV	Photovoltaics (Solar)
RTTR	Real-Time Thermal Rating
SCADA	Supervisory Control And Data Acquisition
SGF WS3	Smart Grid Forum Workstream 3
TOU	Time Of Use

1 Purpose and Scope

The purpose of this document is to detail the requirements of a Business As Usual (BAU) ready version of the Network Planning Design And Decision Support (NPADDS) software tool that was prototyped as part of the Customer-Led Network Revolution (CLNR). This specification is to form the basis of procurement of such a BAU software product by Distribution Network Operators (DNOs) or other interested parties, to be produced by a supplier (referred to as "the supplier" throughout this document). There are many areas that require further innovation work to implement this specification; these are highlighted throughout the document.

This specification details the functional requirements for an NPADDS BAU software product, referred to as "the software" throughout this document, to assist design and planning engineers continue to maintain and economically develop the High Voltage (HV) and Low Voltage (LV) systems as we move to low carbon networks. The scope in terms of network areas is from, and including, the primary transformer to LV feeder ends. References are made in this document to the *NPADDS Prototype Functionality and Benefits Case*,[2] which is also provided as part of this product.

2 Overview of Requirements

For the purposes of production of this specification, and not intended to bias the design approach, functional requirements are split into the following sections:

- **Software Implementation**: describes requirements on software access, languages, products and architectures;
- **Database:** holds and updates network data for all forms of network analysis in the software;
- **User Interface:** responsible for enabling the user to view, select, and edit networks for assessment;
- **Workflows:** describes requirements on the workflow processes guiding users through the features and functions of the software;
- **Network Assessments:** responsible for performing or facilitating network assessments, and comparing performance against standards and limits;
- **Network Solutions:** responsible for ranking headroom solutions in order of merit, and enabling detailed assessment of traditional network reinforcement and 'smart' solutions;
- **Scenario Forecasts:** responsible for generating future scenarios of load growth and Low Carbon Technology (LCT) uptake and assessing network impact;
- **Policy Compliance Search:** responsible for identifying policy and guidance documentation relevant to assessment tasks or keyword searches; and
- **Novel Functionality to be Developed:** outlines features that would incorporate emerging data sets and knowledge, and that require substantial innovation.
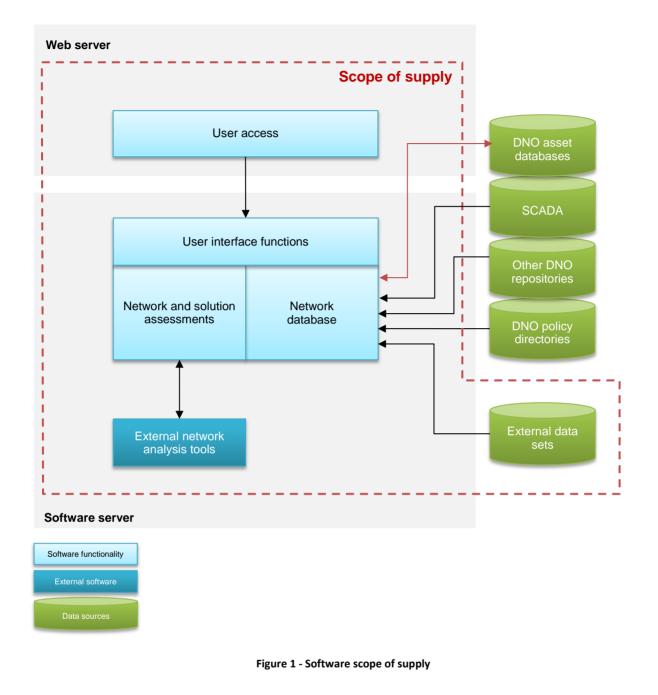
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[2] CLNR-L255: NPADDS Prototype Functionality and Benefits Case.

2.1 The structure of this document

2.1.1.1 This document has been arranged in to the following sections:-

2.1.1.2 Non-Functional Requirements are outlined in Section 4, listing requirements on installation practices, management of the software, and other practical aspects.

2.1.1.3 An *NPADDS Prototype Functionality and Benefits Case* document is available that presents the scope and approach taken by the software prototype work as part of CLNR (Section 1). This document can be read for guidance, but shall not be taken as inferring any particular architecture for the software specified here.

2.1.1.4 Section 5 provides an overview of the development and deployment work required to build on the prototype work completed as part of CLNR in order to deliver a product that meets this specification.

2.1.1.5 The software shall include or facilitate network assessment functionality that is comparable to that of existing products used by DNOs for network planning and design (such as DEBUT, DINIS, IPSA and DIGSILENT).

2.1.1.6 It shall also include additional functionality that may require development by the network modelling tools supplier in collaboration with a DNO for areas that cannot at this time be specified in detail.

2.1.1.7 The software will sit at a business operations level and act as a platform between DNO's network data and a range of network assessment tools. Use of external network assessment tools (DEBUT, IPSA and other models) is required. Network analysis functionality may also be implemented internally within the software where appropriate.

2.1.1.8 The software shall interface with the DNO's existing asset databases and data repositories and be capable of requesting and receiving updated network data on a regular basis.

2.1.1.9 Any data relating to the DNO's network that is used within the software for analysis purposes shall be stored within the software database either temporarily or permanently.

2.1.1.10 Chosen updates to network assets and configurations made within the user interface shall also be written to the DNO's existing network and asset databases.

2.1.1.11 Figure 1 provides an overview of the scope of supply. The supplier shall be responsible for the integration of any external tools and data sets into the software.

Figure 1 - Software scope of supply

2.2   Specification for the development of the new Software Tool

2.2.1.1   The goal of the software is to provide a DNO with a next generation network planning and design tool that will:

- Add value to a DNO's existing BAU activities, by utilising modern database structures, network assessment tools, and customer classification methods; and
- Introduce new facilities for the analysis of Low Carbon Technologies (LCTs), conventional solutions and smart grid solutions.

2.2.1.2   The core functionality of the software is to assess network performance against limits and standards within the context of the DNO's design and planning policies, and to propose and assess the potential of conventional and smart solutions to keep the network within acceptable parameters.

2.2.1.3   The software shall be designed in a forward compatible manner and be modular in nature. The approach shall not prevent future versions of the software from incorporating Emerging trends in network assessment, once these mature sufficiently to be applied in BAU practice.

2.2.1.4   The software shall provide functionality that is relevant to the network analysis tasks undertaken by DNO Connection Engineers, Designers and Planners.

2.2.1.5   The software is designed to undertake network assessments on DNO's specific network topology rather than using generic network synonyms.

2.2.1.6   Networks at both LV (below 1,000V) and HV (greater than 1,000V and below 22kV) levels shall be represented and analysed. The software must be able to accommodate any nominal voltages that are present within the DNO's LV and HV networks.

2.2.1.7   The software shall be able to accommodate the DNO's entire LV and HV network licence area(s).

2.2.1.8   The software shall be capable of handling meshed networks at HV.

2.2.1.9   Procurement of the software should seek to implement an enduring BAU tool that the DNO is able to integrate with their existing systems without extensive modifications. Implementation shall be in parallel with existing systems to ensure a smooth transition. The software shall interface with the DNO's existing network databases and be possible to operate by DNO users within their standard Personal Computer (PC) desktop environment.

2.2.1.10   Implementation and design of the software shall be appropriate for live use by DNOs in a BAU environment, including but not limited to:

- Links with the DNO's asset databases, and other data repositories that enable import and translation of network data into appropriate formats;
- Network assessments that are completed within suitable operational time scales;
- A simple, flexible user interface appropriate for DNO staff; and
- Simultaneous multiple users.

2.2.1.11   Network assessments that shall be accessible via the software are:

1) Headroom assessments for voltage considering unbalanced loads
2) Headroom assessments for power flow considering unbalanced loads
3) Loss calculations
4) Cable thermal analysis
5) Transformer thermal analysis
6) Security of supply (contingency) assessment

2.2.1.12 Network assessments that shall be developed in collaboration with the DNO are:

1) Fault level assessment
2) Derivation of protection settings and fuse values
3) Analysis of disturbing loads
4) Transients and stability assessment
5) Assessing Automatic restoration methods (APRS)

2.2.1.13 The software shall be capable of assessing the impact on network thermal and voltage headroom of the following components and control strategies, in addition to standard cables/lines and transformer equipment, and the configurations associated with link boxes, fuses, switches and circuit breakers:

1) On-Load Tap Changer (OLTC) transformers
2) OLTC Line Drop Compensation (LDC)
3) OLTC Negative Reactance Compounding (NRC)
4) Switched capacitors
5) Voltage regulators
6) Generators in PV-mode
7) Electrical Energy Storage (EES)
8) Demand Side Response (DSR)

2.2.1.14 Users shall be able to add connection points, network assets and control strategies, or alter the properties of existing ones, to then evaluate the performance of different designs.

2.2.1.15 The approach shall enable different approaches to network assessments appropriate for LV and HV voltage levels.

2.2.1.16 Electrical network model data as necessary, with connectivity references are required for the software in order to carry out network assessments.

2.2.1.17 The software shall be able to simulate demand and generation connected at LV and HV. This will include Electric Vehicles (EVs), Heat Pumps (HPs) and solar Photovoltaics (PVs) connected at LV, with the adaptability to incorporate further LCTs.

2.2.1.18 Given a headroom problem on a specific network, the software shall produce a list of potential network design interventions ranked based on merit and the cost of the interventions. The user shall be able to select and design such solutions in detail and asses their impact on a specific network.

2.2.1.19 The software shall be flexible to changes in thinking and the advent of new technology, as the industry is predicted to be entering a period of rapid change. In particular, it shall be designed in an extendable way that enables further components or functionality to be incorporated in future versions with respect to analysis of additional LCTs and 'smart' network design interventions.

2.2.1.20 Suppliers should not take the structure of the functional and non-functional specifications laid out in this document as inferring any preferred architecture for the software.

3 Functional Requirements

3.1 Software Implementation

3.1.1 User Access

3.1.1.1 Application code, documents, external software files and licences, data sources and any other files required to run the software shall be hosted on a centralised server within the DNO's corporate network.

3.1.1.2 The software front end shall be a web-based application such that users are able to run it from within the DNO's standard desktop environment with a connection to the corporate network, using no desk top applications besides a standard web browser.

3.1.2 External Software

3.1.2.1 The software may interface with external software that carry out specific forms of network assessments (e.g. load flow engines) or make use of services such as database frameworks. Where this is the case, the user should be presented with information that states what external software is used.

　　3.1.2.1.1 Where external network assessment tools are used, the user shall be able to access any intermediary text files that pass input and output data to and from the external application, such that the user can re-run the same assessment via the external network tool in isolation of the software specified here.

　　3.1.2.1.2 Any results generated from network assessments shall be stored on a central server and on local PCs to enable all users to access results.

3.1.2.2 The supplier shall advise the DNO of any specific third party software licences required. The DNO, in consultation with the supplier, shall procure licences as necessary.

3.1.3 Software Languages and Architecture

3.1.3.1 The application code and wrappers for interfacing with external software shall be written in mainstream programming languages that benefit from ongoing support from the software language creator (example Microsoft C#.NET).

3.1.3.2 The software shall be implemented as a so-called Domain Driven Design, where functionality is defined as distinct models and software layers to facilitate ongoing development and flexibility.

3.2 Database

3.2.1.1   The software shall be supported by two conceptually separate databases, although physically these may be implemented within a single database structure referred to as "the database" within this specification:

- A Network Database that holds DNO-specific network information; and
- A Configuration Database that holds generic network data, such as for example standard definitions of cable types or consumer classes, as well as any other data required for the software's functionality.

3.2.1.2   Local server based database solutions are preferred, however, the DNO may be open to the use of an external database solution.

3.2.2   DNO Data Sources

3.2.2.1   The database's design and procedures shall be such that it is capable of efficiently importing and storing data that covers the DNO's entire licence area(s) from sources including, but not limited to:

- Network asset databases, as required for
  - LV asset properties
  - HV asset properties
- Demand data repositories, as required for
  - Metered load
  - Measured network data
  - SCADA data
  - Smart meter aggregated data
- Customer models
  - Customer attributes such as meter class, annual consumption and phase
  - PV, EV and HP ownership and device details.
- DNO policy directories
  - A range of design and planning policy documents, determined by the DNO
- Cost books
- Network schematics

3.2.2.2   The software shall be able to maintain a link with the DNO's source data and a procedure shall be implemented such that updates to the source data are imported into the software's network database at regular intervals automatically. Frequency of such updates shall be determined by the DNO. It is imperative that this link does not pose any danger of corrupting the DNOs' databases.

3.2.2.2.1   Data transfer methodologies are at the discretion of the supplier, but to be agreed with the DNO. Options may include retrieving solely updated or relevant data, or copying a comprehensive snapshot of the DNO source data such that relevant bits can be retrieved locally in order to reduce the complexity of the link.

3.2.2.3   Procedures shall be implemented as needed that resolve connectivity problems and errors within the data obtained from the DNO's databases.

3.2.2.4   The Network Database shall take input directly from DNO data sources, and may be editable by users and saved back to the DNO core database. In collaboration with the DNO, a specification shall be developed by the supplier to define the interface to the core network database.

3.2.3   External Data Sets

3.2.3.1   External data sets may be incorporated into the software to act as input data or parameters for network assessments and other functionality, such as postcode coordinates. Where this is the case, selected users shall be able to view such data and a description of the source if the DNO deems it necessary.

3.2.3.2   Permissions for use of external data sets shall be secured such that the software can be procured as a single software package with no further permissions required. Any external data sets used must also be approved and licenced by the DNO.

3.2.3.3   A methodology shall be implemented to ensure that any external data sets that are subject to change are kept up-to-date at intervals agreed with the DNO.

3.2.3.4   It is the supplier's responsibility to access and incorporate external data sets and convert them into appropriate formats.

3.2.3.5   Flexibility shall be built in to enable the addition of new external data sets in the future, as improved data becomes available.

3.2.4   Network Data Scope

3.2.4.1   The software shall either

- Hold an electrical model of the DNO's network with sufficient connectivity to enable each type of network analysis defined by Sections 3.5, 3.6, and 3.7; or
- Retrieve an electrical model of the DNO's network from the DNO source data with sufficient connectivity to enable each type of network analysis defined by Sections 3.5, 3.6, and 3.7.

3.2.4.2   Each component within the network shall be identified by a unique ID, location coordinates, and by its connectivity to other components.

3.2.4.3   A standardised format shall be used to represent network assets within the Network Database as far as is practicable, in order to future-proof and enable sharing with stakeholders.   Unless a more suitable alternative is identified, the principles of the Common Information Model (CIM) format shall be adopted for this purpose.

3.2.4.4   The following components and their full connectivity to each other shall be represented by the software at LV, with sufficient properties to enable all functionality in this specification:

- Transformers (Including OLTC, LDC, and NRC)
- Underground cables, overhead lines
- Fuses
- Link boxes
- Customers, with associated LCTs (EVs, EHPs, PVs)
- Stand-alone generators

3.2.4.5   The following components and their full connectivity to each other shall be represented by the software at HV, with sufficient properties to enable all functionality in this specification:

- Transformers (Including OLTC, LDC, and NRC)
- Underground cables, overhead lines
- Substation bus bars
- Switches and circuit breakers
- Link boxes
- Consumers
- Generators

3.2.4.6   The software shall contain references that link each LV transformer to a corresponding HV consumer point, to facilitate sharing of data between network assessments at LV and HV levels.

3.2.5   Network Assets, Consumers and Generators

3.2.5.1   Individual cables, lines and transformers shall be defined as belonging to a particular type, and inherit the equipment properties that have been defined for that particular type.

3.2.5.2   Asset types shall be defined using static ratings, and the software shall be capable of applying such ratings within network assessments. Definitions of assets shall also be sufficiently flexible that cyclic ratings or Real-Time Thermal Rating (RTTR) data could be used to define the capacity of individual assets.

3.2.5.3   The software shall be able to store specific details about network assets that relate to the design but do not affect the assessment, and users shall be able to access such information within the relevant network assessment tools. These shall be defined in consultation with the DNO, but will likely include installation details, such as cable joint types or the use of ducts across roads.

3.2.5.4   Individual LCTs at LV, which shall include EVs, HPs and PVs, will be represented as separate connections at the same node as the LV customer premises where they are installed, to enable their behaviour to be managed as separate entities.

3.2.5.5   Individual consumer connection points shall be defined as belonging to a particular consumer type or classification, and inherit demand parameters and LCT uptake behaviours that have been specified for that particular type or classification.

    3.2.5.5.1   LCT loads connected at consumer premises, such as EVs and HPs, shall similarly be defined as being of an appropriate consumer type.

3.2.5.6   At LV, the definitions of individual consumers and consumer types shall be such that each consumer is associated with half-hourly load profiles that account for diversified demand and meet the requirements of the statistical process specified in ACE49 Design of Low Voltage Networks. Load profiles shall be available for peak winter demand day and a minimum (summer) demand day.

    3.2.5.6.1   LCT loads connected at consumer premises, such as EVs and HPs, shall have associated load profiles in a similar manner.

3.2.5.7   Generators shall also be defined with reference to generic types or classifications, and inherit parameters that have been specified for that particular type or classification.

3.2.5.8   At LV, the definitions of individual generators and generator types shall be such that each generator is associated with half-hourly load profiles that are based on diversified outputs. Output profiles shall be available for a peak winter day and a minimum (summer) day.

3.2.5.9   At HV, it shall be possible to associate each individual consumer/generator with one or several unique fixed demand/output levels, for a winter weekday and summer weekday. These would likely include rating or thermal demand indicator values for consumers, and rating for generators.

3.2.5.9.1 HV consumer and generator definitions should also be such that they could also be associated with half-hourly load/output profiles once suitable data becomes available for this purpose.

3.2.5.10 The definition of consumers shall be designed in a flexible manner that would enable demographics-related input data, such as income levels within a particular post code, to be used to classify consumers in a way that enables a more specific allocation of representative load profiles, LCT uptake behaviours, or load profiles associated with installed LV LCT loads such as EVs and HPs.

3.2.5.10.1 Similarly, area-related input data, such as weather statistics within a particular post code, should be possible to use to classify generators such as PVs in a way that enables a more specific allocation of representative output profiles.

3.2.5.11 Via the Settings (Section 3.3.2.1.2) in the user interface, selected users shall be able to permanently edit all properties of types of network assets, consumers and generators, as well as add definitions of new types.

3.2.5.12 The design shall be expandable in such a way that further representative days can be added to the definition of load profiles and generator output profiles, beyond a winter and a summer day, if and when appropriate source data becomes available.

3.2.6 Network Data Layers

3.2.6.1 A method shall be implemented whereby a network design scheme can be stored within the software and flagged through the construction lifecycle, for example as being 'under quotation', 'approved', 'commissioned', 'awaiting build', and finally implemented 'as built' and part of the permanent network model.

3.2.6.2 A method shall similarly be implemented whereby customer connection requests are tracked within the software and flagged as being for example 'under assessment', 'approved', and finally implemented 'as built'.

3.2.6.3 A method shall also be implemented that tracks recent assessments on the network, as specified by the DNO, such as for example which new connection requests have been carried out, when, and by what user.

3.2.7 Additional Data

3.2.7.1 The Configuration Database shall be able to store additional data, including but not limited to:

- Configurations, default parameters, and generic input data required for network assessments, cost-benefit analysis, scenario forecasts and solutions assessments;
- Policy clauses and access details for the related policy documentation;
- Assessment results;
- Temporary amendments to network areas, where saved by user for future use; and
- Further data required for the software functionality such as mapping tiles and post code coordinate tables.

3.2.8   Saving Workflow Cases

3.2.8.1   The software shall be able to save the details of a workflow case carried out by a user, including any edits done to the network and results of any assessments, such that these can be re-loaded for continued analysis in a separate session. Such saved data must not affect the original network model stored in the Network Database.

   3.2.8.1.1   A saved assessment shall be possible to re-open in such a way that the user can return to a previous point in the workflow and rework from there.

3.2.8.2   A process shall be provided that enables selected users to save designs and new connections as belonging to a particular layer, as per Section 3.2.6.1 and 3.2.6.2.

3.2.8.3   The most recent network assessment results should always be stored for a portion of network that has not been altered from its original properties within the Network Database.

3.3   User Interface

3.3.1.1   A process-based user interface shall be included that guides users through a set of steps related to connection, design or planning activities. It is paramount that design and development activity is undertaken in collaboration with the DNO such that the intent and usability of the software is not lost.

3.3.1.2   The user interface shall be platform independent and able to run on the DNO's standard PC environment or on the DNOs servers.

3.3.1.3   The specific design of the interface shall be at the discretion of the supplier. The key interface requirements are:

- A logical layout with transparent design;
- Workflows that are appropriate for DNO activities;
- A Visual Design Environment where a network area can be selected, its components and configuration can be viewed and temporarily edited, and design interventions can be added;
- Presentation of assessment results and policy search results;
- Ability to view and configure assessment settings, default parameters, and definitions, where appropriate;
- A means to save and re-load assessment results and configurations; and
- Access to external network assessment input and output files.

3.3.2   Main Sections

3.3.2.1   The main menu of the user interface should enable the user to access functionalities including but not limited to the following.

   3.3.2.1.1   **Assessments -** Users shall be able to:

- Start a new analysis, or re-load and continue a previously saved assessment, as per the workflows defined in Section 3.4.

- Review results of automated assessments as defined in Section 3.4.2

3.3.2.1.2 **Settings -** Users shall be able to view the configurable settings that define the properties of network assessments and solutions assessments, such as permissible voltage headroom thresholds or solution template parameters. Selected categories of users shall be able to permanently edit these, via the user interface.

3.3.2.1.3 **Policies -** Users shall be able to use a keyword search to find clauses from planning documentation and guidance, and then be able to open the original document file, as per the Policy Compliance Search in Section 3.8.

3.3.2.1.4 **Calculator -** Users shall be able to use a built-in calculator provided by the software to quickly convert between currents and power at different LV and HV voltage levels, obtain typical fault level currents at different LV and HV levels, and other similar features defined by the DNO. This tool shall be easily accessible from within the user interface at all points, including within other workflows.

3.3.3 Visual Design Environment

3.3.3.1 A Visual Design Environment shall be included as part of the user interface that displays the design of a network area and enables the user to interact with it. It is a core part of the software, and shall be finalised in conjunction with the DNO to ensure the design and features are aligned with their requirements.

3.3.3.2 A geographical network map showing all network components within a chosen area shall be included.

3.3.3.2.1 The map shall be capable of displaying network performance parameters next to assets, as per Section 3.3.3.7.

3.3.3.2.2 Users shall be able to zoom in and out, and drag the map in order to access different areas.

3.3.3.2.3 Users shall be able to toggle a background to the network map between a street map, a satellite map, or no map at all.

3.3.3.3 Users shall also be able to toggle to view HV networks as a line diagram as an option to the geographical network map specified in Section 3.3.3.2.

3.3.3.4 Visual network representations shall have the ability to highlight components that are part of layers that are not yet a permanent part of the network as per Section 3.2.6, in such a way that users can tell them apart.

3.3.3.5 Links shall be provided from each network area to access any related scheme papers and construction drawings, where the DNO has these available in their core asset database.

3.3.3.6 The user interface shall enable the user to select the portion of the DNO's network that is to be assessed, referred to as the network under study:

3.3.3.6.1 The user shall be able to select to carry out an assessment on standard DNO networks stored in the software database, or to read in an independent network definition as required.

3.3.3.6.2 The user shall be able to search for a relevant post code, select a substation name from a list in a user-friendly manner, or provide Easting/Northing coordinates. This shall bring up and display the appropriate geographical area within the Visual Design Environment map defined in Section 3.3.3.2.

3.3.3.6.3 The user shall then be able to click on a network component on the map to specifically select the associated network portion for analysis.

3.3.3.6.4 Within the Visual Design Environment map the user shall be able to open and close any switches present in the network in order to restrict or reconfigure the network that is to be assessed. The user shall also be able to click on a cable segment in order to elect to switch it out entirely, without the presence of a switch.

3.3.3.6.5 Selected users shall be able to elect to adjust the network under study to reflect a particular layer, as defined in Section 3.2.6, for example to assess the network 'as built' or including changes in the design that have been 'commissioned' etc.

3.3.3.7 Users shall be able to review network properties, assessment results, and carry out thermal equipment analysis via the display of a network area within the Visual Design Environment. It shall be possible to:

3.3.3.7.1 Access design properties of each individual asset and defining properties of each individual connection point.

3.3.3.7.2 View network assessment results across individual nodes and segments of the network in a user-friendly manner, with load flow results shown as default. Users shall be able to toggle to view different result variables. The display shall highlight locations of the worst results across the network under study, and provide a facility that enables these to be quickly identified by the user.

3.3.3.7.3 View a plot of assessment results along feeders connected to a transformer, by distance to the transformer.

3.3.3.7.4 Launch a Cable Thermal Analysis (Section 3.5.3) for an individual cable segment, and launch a Transformer Thermal Analysis (Section 3.5.4) for an individual transformer.

3.3.3.7.5 View a 'heat map' for primary transformers showing the thermal headroom available, to provide users with an indication of where demand can be accommodated.

3.3.3.7.6 Export assessment results to a common spreadsheet format for users to perform bespoke manipulation.

3.3.3.7.7 View details of recent assessments that have been carried out by different users on the network area, as per Section 3.2.6.3.

3.3.3.7.8 View the number of connection points on each feeder.

3.3.3.7.9 Indicate the location of one or several open points on a network and display the number of consumers who are connected to that conductor segment and would lose supply in the event of a fault, accounting for the connectivity associated with the present network configuration.

3.3.3.7.10 View network components and connection points associated with one or two selected phases as well as all three phases, with all features applied as above.

3.3.3.8 As source data for these features, it shall be possible to display the results from the most recent saved assessment as per Section 3.2.8.3 as well as newly generated results, depending on whether the features are accessed before or after an assessment. Details shall be agreed with the DNO.

3.3.3.9 Selected categories of users shall be able to use the network display in the Visual Design Environment to edit the design properties of existing network assets, and define properties of existing connection points (consumers, generators).

3.3.3.9.1 This shall include the ability to temporarily add and define a disturbing load as part of an existing connection point.

3.3.3.10 Selected categories of users shall also be able to use the network display in the Visual Design Environment to create new network assets and connection points.

3.3.4 User Categories

3.3.4.1 User categories shall be implemented within the software in such a way that DNO staff with different functions within the business are able to access only the portion of the software that are relevant to their work. Such categories are to be worked out in conjunction with the DNO, but may include:

- Connection Engineer
- Designer
- Planner
- Administrator

3.3.4.2 User privileges shall also be implemented such that only a selected set of users, as defined by the DNO, are able to temporarily or permanently make changes or add data within the software.

3.3.4.3 User privileges are also described in Section 4.5.1.5.

3.4 Workflows

3.4.1.1 The user interface shall guide users through a set of workflows that are specific to the type of activity that is carried out, and could involve several types of network assessments in succession. The aim is to ensure that users are able to deal with each key aspect of an activity within one streamlined process as part of the workflow.

3.4.1.2 Such workflows must correspond with the existing working practices of DNO staff, and it is crucial that these are finalised based on close collaboration with the DNO. Details

provided in this section of the specification are for initial guidance only. Details such as user access to select settings and assessment-specific options shall be agreed with the DNO.

3.4.1.3   A **"Designer – existing network"** workflow shall include the following steps:

1) Select a network area for assessment
2) Presentation of relevant policy clauses
3) Review previous assessment results
4) Edit existing assets and connections
5) Offer user the option to carry out or skip each of:
    - Perform a load flow headroom assessment, and review results
    - Perform a contingency assessment, and review results
    - Perform a fault current / fusing assessment, and review results
    - Perform a power quality assessment (if implemented), and review results
6) Review summary results
7) Offer user the option to carry out or skip each of:
    - If a normal/contingency operation headroom problem is found, perform a solution assessment to resolve problem
    - If a fault current headroom is found, perform a solution assessment to resolve problem

3.4.1.4   A **"Connection engineer – new connection"** workflow shall include the following steps:

1) Select a network area for assessment
2) Draw cables/lines for the new connection
3) Add and define the new connection(s)
4) Presentation of relevant policy clauses
5) Perform the following:
    - Load flow headroom assessment
    - Fault level / fusing basic assessment
    - Disturbing load assessment (Stage 1) as needed
6) Review summary results
7) Present yes/no indication if connection can go ahead without further analysis by designer for each of the assessment areas
    - If no: Save assessment such that this can be reopened by a designer at the appropriate place in their workflow in Section 3.4.1.5.

3.4.1.5   A **"Designer – new connection"** workflow shall include the following steps:

1) Select a network area for assessment
2) Review previous assessment results
3) Edit existing assets and connections
4) Draw cables/lines for the new connection(s)
5) Add and define the new connection(s)
6) Presentation of relevant policy clauses
7) Perform the following:

- Load flow headroom assessment, and review results
- Fault current / fusing assessment, and review results
- Disturbing load assessment (Stage 2 onwards), and review results

8) Review summary results
9) Offer user the option to carry out or skip each of:
   - If a normal/contingency operation headroom problem is found, perform a solution assessment to resolve problem
   - If a fault current headroom problem is found, perform a solution assessment to resolve problem
10) Perform Connection cost apportionment assessment, and review results

3.4.1.6   For the purposes of new connection workflows (Sections 3.4.1.4 and 3.4.1.5), results presented shall include a summary pertaining to the specific node with the new connection. This shall include:

- Headroom results under normal conditions versus threshold setting (load flow)
- Loop impedance results versus threshold setting (fault level)
- Voltage drop on the service cable versus threshold setting (disturbing loads and LCTs)
- Power Quality results as appropriate

3.4.1.7   A **"Designer – future scenario assessment"** workflow shall include the following steps:

1) Select a network area for assessment
2) Presentation of relevant policy clauses
3) Review previous assessment results
4) Edit existing assets and connections
5) Perform multi-year load growth and LCT uptake assessment
6) Review summary results
7) If a headroom problem is found, perform a solution assessment to resolve problem

3.4.1.8   A **"Planner – wide area assessment"** workflow shall include the following steps:

1) Select network areas for assessment
2) Review previous assessment results
3) Set parameters for the assessment (e.g. date range)
4) Perform multi-area load growth and LCT uptake assessment
5) If headroom problems are found, perform a solution assessment (template) to resolve problem
6) Review summary results
7) Export data in spreadsheet format

3.4.1.9   A **"Designer / Planner – bespoke assessment"** workflow, which shall be enable the designer or planner to run different types of tests and analysis without being inhibited by a fixed wizard-style process. It shall be designed for maximum flexibility, with the ability to step back through the process as needed to follow a different path of analysis at any point. It shall include the following steps:

1) Select a network area for assessment
2) Review previous assessment results
3) Search for and review policy documentation on a chosen range of topics as per Section 3.8.1.3.2.
4) Ability to edit network in all available ways
5) Ability to perform any network assessment specified in Section 3.5
6) Ability to apply any scenario forecasts as specified in Section 3.7
7) Ability to apply and assess any solution/combination of solutions as specified in Section 3.6.3, regardless of whether a headroom problem has been identified and without a ranked order of solutions.

3.4.1.10 Ahead of each workflow, the user shall be prompted to review the settings in Section 3.3.2.1.2 with the ability of selected types of users to edit these.

3.4.1.11 Throughout any workflow, the user shall have access to the relevant policy clause results as per Section 3.8.1.3.

3.4.1.12 Throughout any workflow, the user shall be presented with the option of saving the workflow case as per Section 3.2.8.1.

3.4.1.13 At the end of the appropriate workflows, selected categories of users shall also be able to save designs and new connections as belonging to a particular layer, as per Section 3.2.6.1 and 3.2.6.2. Details of such arrangements shall be agreed with the DNO.

3.4.2 Automated Assessments

3.4.2.1 A method shall be implemented that carries out a regular headroom assessment on a chosen section of the DNO's LV and HV networks, and updates the saved results within the software as well as produces a report of any networks that require attention. Timing of such assessments shall be agreed with the DNO but may be weekly or monthly and take place overnight when computer resources are available.

3.4.2.2 A method shall also be implemented that enables a user to run scenario forecast assessments (Section 3.7) on a larger selected set of networks, scheduled to take place at a particular time. This assessment is intended to provide the user with an overview of the number of LCTs that can be installed in each network area, in order to then trigger the appropriate action.

3.4.2.3 Selected sets of users shall be able to view the results of such automated assessments.

3.4.2.4 Simplified heuristic methods may be implemented in place of full load flow, if approved by the DNO, to reduce the computational burden involved.

3.4.2.5 The selected set of networks that are assessed could span the full licence area, or be limited to a proportion of network areas that are known to operate closer to threshold constraints. Areas that have seen no change may be omitted.

3.5 Network Assessments

3.5.1.1 External software tools such as DEBUT or IPSA may be called upon to perform the required network assessments.

3.5.1.1.1 Where external software packages are utilised for network assessments, the user shall be able to access input and output files that hold the input and output data from such tools. The user shall also be able to open the relevant external software as a free-standing application, and view the assessment carried out.

3.5.1.2 The software's ability to implement individual aspects of network assessments will be dependent upon availability of DNO data. For example, fault current assessments to evaluate whether LV fuse values are appropriate will only be implemented where DNO LV fusing data is accessible.

3.5.1.3 The model shall be capable of sharing results between the network assessment tools. For example, the cable thermal assessment tool should be able to utilise a current load flow profile through a cable segment obtained by the steady-state load flow assessment.

3.5.1.4 Where possible, inputs already provided in other parts of the software or workflows shall be utilised as input for the network assessments, to avoid users having to re-enter information.

3.5.1.5 All network assessments shall be capable of accounting appropriately for any type of network asset and connection point defined in the database as part of the DNO's existing network.

3.5.1.6 The user shall be able to select a network area and voltage level for analysis using the steps outlined in Section 3.3.3.6.

3.5.1.7 Threshold values used to evaluate whether network performance parameters obtained from network assessments are within permissible limits shall be available for users to view within the Settings section (Section 3.3.2.1.2). Selected users shall also be able to edit these.

3.5.1.8 Results from any assessment shall be displayed to the user in whatever format is most appropriate for the workflow in Section 3.4. This shall be agreed with the DNO, but may for example include showing a table of before/after results following a 'new connection request assessment'.

3.5.2 Load Flow Headroom Assessments

3.5.2.1 The software shall include a 3-phase unbalanced steady-state load flow tool that calculates power flow parameters within the network area under study, and then evaluates for each asset whether thermal utilisation and voltage headroom are within chosen thresholds.

3.5.2.2 The load flow methodology shall take as input the necessary electrical parameters that describe assets within a network area in order to output:

- Voltage and voltage angle at each node
- Current, and power losses through each branch or line/cable segment
- Real, reactive and apparent power flow and power losses through each transformer
- Real, reactive and apparent power output from each generator

3.5.2.3 The load flow tool shall be able to assess the voltage drops and currents of split phase networks at both HV and LV.

3.5.2.4 The load flow tool shall be capable of modelling unbalanced 3-phase networks at both LV and HV. Selected users shall be given the option of selecting a balanced (auto-rotate) or unbalanced analysis. Where an unbalanced assessment is chosen, the user shall be able to select between:

3.5.2.4.1 Specified phase unbalance at customer level. It shall be possible to incorporate DNO network data stored in the database that states the phase connection of individual single phase customers or the phase imbalance of 3-phase customers. The user shall also be able to click on an individual customers to temporarily configure this data.

3.5.2.4.2 Specified phase unbalance at the network level. The user shall be able to provide a percentage unbalance for the network as a whole, or bias a particular phase, and the model should then allocate phase connections in accordance with this figure or otherwise adjust the assessment in a manner that is approved by the DNO.

3.5.2.5 At both LV and HV the software must be capable of analysing load flow at half-hourly intervals as a Time of Use (TOU) assessment, for a winter day and a summer day. This may be achieved by running repeated individual load flow assessments using an external software, and collating the results. A winter and summer day shall be implemented as standard, with the flexibility of adding further representative days.

3.5.2.6 Consumer demand and generator output shall be treated as follows at LV:

3.5.2.6.1 Half-hourly consumption levels that represent an individual customer at a LV load connection point must be based on diversified demand in line with the DNO's policies.

3.5.2.6.2 Half-hourly consumption or output levels that represent LCT devices such as EVs, HPs, and PVs shall also preferably be based on diversified behaviour for such devices. However simpler power level representations may be chosen if approved by the DNO.

3.5.2.6.3 Where diversified summer profiles are not available from suitable data sets, appropriate assumptions regarding summer load and generator output shall be made in conjunction with the DNO.

3.5.2.6.4 The calculation of diversified demand shall be in line with ACE49 Design of Underground LV Networks.

3.5.2.7 At HV, selected users shall be able to set the type of demand/output data that is to be used for each load/generator connection point, with a default type chosen by the DNO. Options shall include:

3.5.2.7.1 Single levels stored in the Network Database, such as Thermal Demand Indicator values or Rating values for demand. Such definitions shall be defined in consultation with the DNO.

3.5.2.7.2   User-specified power level;

3.5.2.7.3   TOU load profile results saved from a previous LV assessment (Section 3.2.8.3), available at connection points that represent LV/HV substations; and

3.5.2.7.4   Flexibility in the design shall be such that half-hourly profiles at consumer and generator connection points could also be elected in future.

3.5.2.8   Consumer demand and generator output shall be treated as follows at HV for TOU assessments:

3.5.2.8.1   Where half-hourly data is not available (e.g. Sections 3.5.2.7.1 and 3.5.2.7.2), the fixed demand level may be replicated across each half-hourly interval during a day.

3.5.2.8.2   Where summer demand data is not available appropriate assumptions made regarding summer load shall be made in conjunction with the DNO.

3.5.2.9   For HV analysis, the software shall also provide selected users with the option to carry out a worst-case assessment where a single demand level is used to analyse a winter day, and similarly a summer day. The aim of such an analysis is to obtain a snapshot worst-case performance that does not account for the diversity of consumer demand and generator output.

3.5.2.9.1   Where a previous LV assessment is chosen as load data at a LV/HV substation, the maximum winter value shall be used for the winter day assessment and the minimum summer value for the summer day assessment.

3.5.2.10   Selected users shall be able to opt to apply a load allocation method for each individual HV feeder and each individual LV network area. The load allocation will take a single demand figure as input, specified for each feeder (HV) or transformer (LV) by the user, which would typically represent a metered data point with the flexibility to link this to SCADA data. The load allocation algorithm shall distribute this demand figure between the load connection points down-stream on the feeder, in a manner that accounts for the differences in sizes between those loads, to be agreed with the DNO. At HV, two versions of this algorithm shall be provided, where the user-specified demand figure is applied either to the top of the feeder or to the mid-point.

3.5.2.11   The user shall have the option to save values entered for the load allocation with a date stamp (e.g. Summer 14).

3.5.2.12   The software shall provide the option to link LV and HV load flow assessments in the following manner:

3.5.2.12.1   At LV, the software shall provide the option to adjust the input value used for the LV/HV transformer voltage set point at the lower voltage side, based on previously saved HV load flow assessment results for the voltage at the transformer higher voltage side. The transformer ratio and tap setting will be used to calculate LV bar volts from the HV voltage.

3.5.2.12.2 At HV, the software shall provide the option to adjust the power levels at connection points that represent LV transformers, based on previously saved LV load flow assessment results for the loading of those LV transformers.

3.5.2.12.3 The software shall by default apply the most recently saved LV and HV assessments that were carried out on the relevant network area where no temporary amendments to the network were made by the user.

3.5.2.13 The worst-case thermal headroom shall be assessed based on the load flow results and equipment ratings, for the following assets:

- At LV: cable and line segments, transformers, link boxes, fuses; and
- At HV: cable and line segments, transformers, switches, circuit breakers.

3.5.2.14 The worst-case voltage headroom and legroom shall be assessed based on the load flow results, as follows:

3.5.2.14.1 As a percentage of 230V at LV, to enable assessment of compliance with ESQCR Reg 27.

3.5.2.14.2 As a percentage of the nominal voltage level at HV, to enable assessment of compliance with ESQCR Reg 27.

3.5.2.15 Worst-case thermal headroom for any cable and transformer, and worst case voltage headroom and legroom for any node, shall be presented to the user at the end of the assessment for the analysed network area as a whole. Each of these results shall be evaluated against user-defined threshold values, stored in the software, with a clear pass/fail indicated.

3.5.2.16 The user shall be able to elect to display the maximum currents at branches and maximum voltage drops at nodes within the Visual Design Environment across the network area under study.

3.5.2.17 Losses across the network area shall be summed up at feeder level and be presented on a relative basis, in such a way that a change in the level of losses are displayed to the user following an adjustment to the network design.

3.5.2.18 The software shall have placeholders to hold user-entered parameters for the EHV (Extra High Voltage) supply, including:

- X/R ratio;
- Supply voltage at minimum demand; and
- Supply voltage at maximum demand.

3.5.3 Cable Thermal Analysis

3.5.3.1 A cable thermal assessment tool shall be included that assesses the following properties of an individual cable segment, using a DNO approved methodology or a recognised standard:

- Cyclic rating

- Cyclic rating factor
- Average lower loss
- Average annualised loss
- Isolated conductor temperature
- Interactive conductor temperature

3.5.3.2   Input data shall be defined as follows:

    3.5.3.2.1   Required design parameters for each type of cable shall be defined in consultation with the DNO. The user shall be able to temporarily edit these for the purposes of the assessment.

    3.5.3.2.2   Half-hourly load levels during a winter weekday at the individual cable segment shall be provided by a previously performed steady-state load flow assessment.

3.5.3.3   Results shall be displayed to the user along with the Steady State Rating, and a plot showing the load on the cable for each half hour interval of a day against the Cyclic Rating.

3.5.3.4   The user shall have the ability to change the rating value during an assessment (e.g. change from static to cyclic rating).

3.5.4   Transformer Thermal Analysis

3.5.4.1   A transformer thermal modelling tool shall be included that assesses an individual transformer's internal temperature at half-hourly intervals during a winter day. This assessment shall be based on a recognised standard such as BS IEC 60076-7:2005.

3.5.4.2   Users shall be able to select the transformer to be analysed, by clicking on it via the Visual Design Environment or by opening up the Transformer Thermal Analysis tool and selecting a transformer by name from a list provided by the software, narrowed down by HV area.

3.5.4.3   Input data shall be defined as follows:

    3.5.4.3.1   Required design parameters for each type of transformer shall be defined in consultation with the DNO. The user shall be able to temporarily edit these for the purposes of the assessment.

    3.5.4.3.2   Half-hourly load levels at the individual transformer shall be provided by a previously performed steady-state load flow assessment.

3.5.4.4   The model shall present the user with a plot of the half-hourly load and half-hourly internal temperature of the transformer.

3.5.5   Security of Supply (Contingency)

3.5.5.1   The software shall include a tool that aids the user in the assessment of a HV network area under various connectivity configurations for contingency analyses.

3.5.5.2   The tool shall allow the user to create a set of configurations by operating switches within the Visual Design Environment and adding each such configuration to the set to be analysed.

3.5.5.3   The tool shall use switch positions defined as the default setting (normal running) to populate the connectivity model initially. As switch positions are altered by the user to simulate abnormal running arrangements, the user shall have the ability to save multiple configurations.

3.5.5.4   The software shall assess the network headroom (load flow) for each of the network configurations within the set, and present the user with worst-case headroom

performance for each case as per Section 3.5.2.15. An overall pass/fail should also be displayed.

3.5.5.5 A method shall also be provided which suggests optimal open point locations to the user to balance demand on connected feeders and reduce losses. The software shall pick out the configuration with the most favourable combination of available headroom / legroom and losses, using a methodology approved by the DNO.

3.5.6 Fault Level

3.5.6.1 The software shall include a fault level tool that obtains the maximum fault level current through each asset within the network area under study, and then presents whether the fault current is within appropriate thresholds for each asset. It shall be suitable for assessments that comply with G74, IEC 60909 standards, P25/1, and P26 where appropriate.

3.5.6.2 Input shall include the following:

- Graph connectivity of all nodes and branches within the network area under study, from the end of feeders to the lower voltage side of transformers;
- Impedance along network branches;
- Fault level contribution of generators within the network area under study;
- Fault level contribution and upstream impedance at each infeed point to the network area under study; and
- Fault level capability of all connected assets.

3.5.6.3 The user shall be able to elect to display fault level headroom results within the Visual Design Environment at each asset within the network area, highlighting any assets which do not have the required Fault Level capability.

3.5.6.4 Based on the fault level results, the ability of the following types of assets within the network area to withstand the maximum fault level shall be assessed given their fault current rating:

- At LV: cable or line segments, transformers, link boxes, fuses, generators.
- At HV: cable or line segments, transformers, switches, circuit breakers, generators.

3.5.6.5   The fault current assessment shall present the user with overview results, in the form of the minimum fault current 'headroom' across each category of assets in Section 3.5.6.4.

3.5.6.6   At LV, the fault level tool shall obtain the maximum loop impedance of the network in order to compare this against permissible levels, taking as input conductor (phase and neutral) impedances.

3.5.6.6.1   The user shall be able to elect to display within the Visual Design Environment the areas of the network where the loop impedance is above the permissible limit.

3.5.7   Protection

3.5.7.1   The software tool will not directly perform protection studies but will facilitate the data transfer to stand-alone systems that have this functionality.

3.5.7.2   The software shall pull the required data through the DNO's network databases and present it to a separate protection tool. This is intended to prevent the DNO from being required to maintain a separate database for protection assessment purposes.

3.5.8   Disturbing Loads and LCTs

3.5.8.1   The software shall include an analysis tool that assesses the following four forms of impact of disturbing loads on the network area under study, as required, and enables the user to determine whether the load is within permissible tolerances or requires mitigating steps to be taken in order to accommodate it:

- Voltage swells and dips due to the start of a load;
- Voltage unbalance;
- Flicker; and
- Harmonics.

3.5.8.2   Equipment that is likely to be assessed in this manner include individual larger devices such as motors, variable speed drives and synchronous generators, as well as collections of smaller loads such as IT equipment or smaller inverter-based generators.

3.5.8.3   The tool shall take as input the type and size of load that is to be assessed by identifying new or amended connection points within the network area under study and enabling the user to specify which one is to be assessed. It shall then present the required assessment stages as per the DNO's procedures, based on the load properties.

3.5.8.4   The tool shall be designed to reflect the DNO's planning guidance documentation and design standards on disturbing loads such as G5/4-1 ENA ER G5/4 and ETR 122 harmonics, P28 flicker, and P29 voltage unbalance.

3.5.8.5   Load starts, in particular motor starts, that result in voltage dips shall be analysed as follows:

    3.5.8.5.1   An appropriate methodology such as that used within Win-DEBUT or by replicating other existing spreadsheet tools shall be used to calculate the change in voltage within the network area under study that occurs due to the start of an individual load, on the basis of the inrush current as well as a loop impedance assessment at the connection point as per Section 3.5.6.6. The calculation of the voltage drop shall account for voltage regulation at the transformer if appropriate, and be in accordance with ENA P28.

    3.5.8.5.2   The assessment shall take as input the load definition in Section 3.5.8.3, and user entered fields (as would be taken from a customer connection request). Also the ability to define and store standard data tables for common disturbing loads shall be provided.

    3.5.8.5.3   The user shall be presented with the % voltage drop resulting from the load start, compared against a user-defined threshold level stored in the software.

3.5.8.6   Fluctuating loads shall be analysed using a flicker assessment, as follows:

    3.5.8.6.1   Stage 1 LV heuristics assessment shall implement the series of yes/no heuristics rules as per the DNO's policies, and the load definition in Section 3.5.8.3, to determine whether a flicker assessment is required. If a flicker assessment is required, assessment shall progress to Stage 2.

    3.5.8.6.2   Stage 2 LV assessments shall evaluate short term flicker severity values (which considers the percentage voltage change and the time between such changes), and long term severity values (which integrates the short term values over time) as per ENA P28. The output shall state whether flicker severity is below a user-defined threshold, stored in the software, below which connection is considered safe without further investigation. If the threshold is exceeded, the user is alerted that intervention would be necessary.

3.5.8.7   Non-linear loads shall be analysed using a harmonics assessment, based on stages:

3.5.8.7.1   Stage 1 shall be implemented as a decision tree assessment, which identifies whether LV equipment can be connected without further analysis and is based on a set of heuristic rules, as per DNO practice. It shall take as input properties of the individual load provided by the user, as well as tables of admissible harmonics currents stored within the software, with the ability to adjust such values according to fault current as required.

3.5.8.7.2   Stage 2 and further assessments require measurements on site to be taken and used as input, and are necessary only for equipment that does not pass Stage 1. These assessments shall follow the processes laid out in ENA ER G5/4 and ETR 122 and account for the level of background distortion. Harmonic content shall be evaluated against a DNO-specified percentage of measured values that must be below permissible planning levels. These settings shall be incorporated into the software.

3.5.8.7.3   A future methodology may be implemented to estimate the amount of harmonics 'headroom' within a particular network area (see Section 3.9.1.6).

3.5.8.8   The output of the assessment shall state whether the connected equipment is within the admissible limits with respect to the assessments in Section 3.5.8.5.

3.5.8.9   The output of the assessment shall also state which limits have been exceeded in such a way that the DNO should consider taking mitigating steps within the network area.

3.5.8.10   All users shall be able to view input data and settings that are stored within the software, and selected user categories may also be able to edit them.

3.5.9   Transients and Stability

3.5.9.1   The software shall include a facility that enables assessment of transient stability on the LV/HV networks.

3.5.9.2   Implementation of this may be achieved by exporting data into a format that can be read in by an external tool, such as IPSA, without then importing the results back into the software. In this case:

3.5.9.2.1   The software shall gather the required input from the DNO's core network database where available, and pass this to the external tool, and also capture additional input data from the user where this serves to create a user-friendly interface with the external software.

3.5.9.2.2   The user shall be able to easily open up the external tool and be supported as needed to identify any required run-files produced by the software with input data for the transient stability assessment.

3.5.10   Connection Cost Apportionment

3.5.10.1   A tool shall be included that calculates the cost involved in facilitating a new connection request, as per DNO cost books, apportionment rules, and any other DNO-specific policies.

3.5.10.2   Input to the assessment shall consider:

3.5.10.2.1 New network assets that have been defined to accommodate the new connection as part of workflows specified in Section 3.4, including new mains or service cables/lines drawn, and required design interventions identified as part of solution assessments.

3.5.10.2.2 Costs associated with these new network assets, including their installation, as per cost books data stored in the software database

3.5.10.3 Methodology for cost apportionment shall be guided by DNO policies and apportionment rules.

3.5.10.4 The ability to store and use multiple cost books shall be provided.

3.5.10.5 The user shall be presented with the following outputs:

3.5.10.5.1 Costs, per category and in total, attributed to the person/s associated with the new connection

3.5.10.5.2 Costs, per category and in total, attributed to the DNO.

3.6 Network Solutions

3.6.1.1 The purpose of Network Solutions is to support the user in identifying the least cost, technically feasible solution that will resolve a network performance problem. Designers and planners face a growing number of options and will be expected to identify the least cost technically feasible one.

3.6.1.2 The software shall contain two broad areas of solution assessment:

- Solution Templates, to guide planners and designers towards the likely optimum solution;
- Detail solution modelling, to allow designers to understand the effects of specific solutions.

3.6.1.3 When a thermal, voltage or fault level headroom problem is identified by a network headroom assessment, the user shall be presented with a number of potential solutions in their order of merit based on a common set of solution templates. The solution templates will briefly describe the solution parameters in terms of applicability of inclusion on the network, the expected benefits and the cost.

3.6.1.4 It shall be possible to select one or several of these in order to evaluate the detail of the proposition on the specific network area in question.

3.6.1.4.1 The user shall as part of some workflows be able to skip the step where solutions are listed in order of merit, and instead be able to elect to analyse any solution from the solution set in use (see Section 3.6.2.7).

3.6.1.5 The solution templates and the parameter values within those templates shall be developed in collaboration with the DNO.

3.6.1.6 The supplier shall implement a design tool to allow users to enter a variety of solutions to the network model. These shall be implemented mostly through direct manipulation of a

drawing toolbar and drag and drop onto the map or an interactive graph. The features shall include:

- Adding, deleting and modifying customer connection points;
- Modifying customer details (profile type, annual consumption, max demand etc.)
- Adding, deleting and modifying network components;
- Adding, deleting and modifying connectivity arrangements; and
- Applying a variety of solutions as described below.

3.6.2 Solution Template Ranking

3.6.2.1 A function is to be provided that uses rule based method to rank solution templates in their order of merit given a particular thermal or voltage headroom that needs to be released. It shall consider combinations of solutions as well as individual solutions.

3.6.2.2 The merit order shall combine technical and financial implications, some of which will be based on experience and DNO knowledge of the technology, and will consider the following generic characteristics of each solution in a way that is agreed with the DNO:

- Ability to release sufficient thermal or voltage headroom;
- Impact on fault current headroom and power quality in the network;
- Flexibility and cross-benefits to the network;
- Capital and operating cost on a Net Present Value basis;
- Life expectancy;
- Eligibility on a particular type of network; and
- Compatibility (synergies or negative interactions) with other solutions.

3.6.2.3 Information that describes each solution at LV and HV in terms of the properties listed in Section 3.6.2.2 should be held in a library within the software database. Properties associated with each solution shall:

3.6.2.3.1 Be approved by the DNO;

3.6.2.3.2 Be available for selected users to edit within the user interface, including the compatibility with other solutions to account for DNO practices; and

3.6.2.3.3 Be available for all users to view within the user interface.

3.6.2.4 The methodology and logic of an external tool such as TRANSFORM may be used to implement the merit order calculation and guide the way information about each solution is defined and presented.

3.6.2.5 Solution definitions from Smart Grid Forum Workstream 3 (SGF WS3) may be used as a starting point.

3.6.2.6 The implementation shall be flexible in such a way that new types of solutions could be added, including those that depend on an enabling technology such as monitoring or communications, whose financial impact and other implications must then be accounted for.

3.6.2.7 The software shall group individual solutions into solution sets, such that only solutions within a particular solution set are considered by the ranking process and made available to the user for detailed evaluation.

3.6.2.7.1 All users shall be able to see which solution set is in use.

3.6.2.7.2 Selected users shall be able to select which solution set is to be utilised.

3.6.2.7.3 Selected users shall be able to permanently add a new solution to a solutions set, provided all the characteristics are appropriately described as in Section 3.6.2.2.

3.6.2.7.4 Selected users shall be able to add new solution sets, including replicating and then amending an existing solution set to avoid duplication of work.

3.6.3 Detailed Assessment of Solutions

3.6.3.1 The user shall be able to select a proposed solution in order to move to a dedicated 'solution design' portion of the user interface where the user can evaluate solutions in detail on the network in question and consider its specific design.

3.6.3.1.1 Design parameters of the solution shall be available for user configuration, so that it can be tweaked for the individual circumstances within the particular network area in order to identify the most suitable design.

3.6.3.1.2 The user shall be able to reconfigure the design parameters at any point within the workflow in order to re-asses the solution.

3.6.3.1.3 Limits shall be implemented in collaboration with the DNO that prevent users from entering design parameters that are unfeasible or yield unreasonable results.

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3.6.3.2 It shall be possible to assess several solutions within the same work session.

3.6.3.3 After evaluating a chosen solution in detail, the user shall be able to return to the list of proposed solutions 'with a clean slate' in order to try out a different solution without the need to rerun the original headroom assessment.

3.6.3.4 The user interface shall step the user through each of the assessment types (load flow, fault level etc.) in turn, for the relevant portion of network.

3.6.3.5 The software shall present the effect of the solution, as a before and after summary, to the user as a set of key metrics including:

- Profile plots of half hourly maximum demand for the transformer or conductor;
- Profile plots of half hourly minimum and maximum voltages for the conductors;
- Change in fault level headroom of the network area;
- The impact on losses for the network area.

3.6.3.6 Where practical, the results of the solution modelling shall be presented in tabular form and be shown on the map adjacent to the appropriate asset.

3.6.4 Cost Benefit Assessment of Solutions

3.6.4.1 An assessment of the cost of deploying a specific instance of a solution shall be made such that the software can inform of the cost-benefit case. The user shall be presented with the generic costs for the solution type based on the solution template and shall have the ability to edit the costs in line with the expected outturn from the specifics of the design under consideration.

3.6.4.2 While working to resolve a particular headroom problem on a specific network, the user shall be able to store multiple solution assessments on a 'clipboard', where a summary of the design parameters and cost-benefit results are clearly displayed and the particular solution assessment can be re-accessed in the user interface as needed. The role of the clipboard is to facilitate comparisons of detailed solution assessments.

3.6.4.3 The user shall be able to save the headroom problem case and the solutions clipboard in such a way that it can be reopened and continued at a different time.

3.6.4.4 A flexible user interface shall be implemented such that the user can return to different stages in the solution assessment in order to, for example, amend the design parameters.

3.6.4.5 It shall be possible to deploy combinations and multiple solutions to a network area, e.g. several voltage regulators along a single feeder. Significant flexibility is required in the cost benefit assessment engine to cater for complex solutions and additional cost factors.

3.6.4.6 The software shall be capable of modelling a number of solutions, both conventional and smart, based on their costs and merits. The specific solutions that are to be modelled are:

- Operating/optimising existing assets with alternative settings or functions;
- Replacement of assets with higher fault level or thermal ratings;
- Network configuration changes such as splitting feeders and transferring load onto neighbouring feeders;

- Installing new assets; and
- Generators with fixed power factors or operating in PV-mode.

3.6.4.7 The software shall allow a user to capture costs as they modify existing network components or add new assets. The cost benefit shall keep a running log of the expected cost to deploy a solution, referring the designer to cost books for generic assets as necessary (e.g. £ per metre of cable laying).

3.6.5 Optimising Existing Assets

Automatic OLTC

3.6.5.1 Users shall be able to assess the impact of the inclusion of automatic OLTC on HV/LV transformers on the voltage profile of the downstream network. The OLTC and Automatic Voltage Control (AVC) relay design parameters shall be configurable by the user.

3.6.5.2 Users shall be able to assess the impact of changes to AVC fixed voltage set points at EHV/HV transformers on the voltage profile of the downstream network (including LV feeder ends). The OLTC design parameters shall be configurable by the user.

3.6.5.3 User-configurable design parameters shall include:

- Voltage set point;
- Dead-band;
- Tap range and step; and
- Voltage regulation of the transformer winding.

3.6.5.4 On the basis of the user's selected voltage set point level, for new assets, the software shall evaluate the tap range +/-% required in order to bring both the maximum and minimum voltages to within voltage limits. The Tap range +/-% is expressed as a percentage of the nominal output voltage of the transformer.

3.6.5.5 The software shall also propose a voltage set point, based on a balanced risk of over and under voltage. This would be done by bringing both the maximum and minimum voltages to within the voltage headroom limits with as equal a margin to the limits as possible.

3.6.5.6 Users shall be able to assess the impact of Negative Reactance Compounding (NRC) within AVC relays applied to EHV/HV transformers.

Line Drop Compensation (LDC)

3.6.5.7 Users shall be able to assess the impact of deploying or activating the LDC algorithm within AVC relays on the voltage profile of downstream network areas.

3.6.5.8 In addition to the AVC parameters, user-configurable design parameters for LDC shall include:

- Full load;
- Minimum load;
- Voltage set point at full load;
- Voltage set point at minimum load; and

- Line resistance and reactance.

3.6.5.9   The software shall use the network modelling results to display the modelled maximum and minimum load seen at the transformer to guide the user input.

3.6.5.10 For EHV/HV transformers, the software shall also have user entered placeholders for supply voltage input levels on the EHV side of the transformer during maximum load and minimum load, to be used, along with the transformer parameters, to assess the suitability of the tap range to maintain headroom levels. At LV, the user should have the option of similarly defining such voltages, or using those available from previous HV assessments within the software which shall then be displayed to the user.

3.6.6   Asset Replacement

3.6.6.1   The software shall allow the user to quickly model the effect of replacing assets by modelling changes in design parameters. Examples of this modelling shall include:

- Changing the rating of a transformer;
- Changing the operating regime of the voltage control (as Section 3.6.5);
- Changing a conductor, or parts of a conductor, to a different type;
- Changing the fault level capability of an asset; and
- Changing the asset type.

3.6.6.2   The user shall be able to select one or several assets on the map or on a graph (Section 3.6.1.6), be presented with the option to either replace with an alternative specification against a standard list in the Configuration Database.

3.6.7   New Network Assets

Feeder Splitting

3.6.7.1   Users shall be able to assess the impact of splitting a feeder within LV and HV network areas. This shall involve the user having the ability to lay a new feeder out of a substation to a downstream point of an existing feeder, breaking the connection to the existing feeder and connecting the new feeder such that it picks up the remaining downstream load.

3.6.7.2   The user shall be able to delete mains and service cables/lines that link connection points to a feeder, and draw new mains and service cables/lines to link them up to alternative feeders. The user shall be able to select the cable or overhead line types of new feeder segments from a list linked to standard types within the Configuration Database.

3.6.7.3   A list shall be displayed to the user showing the length and associated cost of each new segment of cable or overhead line and the number of joints that have been modified.

Re-configuration

3.6.7.4 Users shall be able to assess the impact of load shifting by reconfiguration within LV and HV network areas. This involves shifting connection points from one existing feeder to another less highly loaded one.

3.6.7.5 The solution assessment shall concern a particular network area under study, involving multiple feeders, which should include the individual feeder that features the worst thermal cable headroom levels.

3.6.7.6 A map, of the kind defined in Section 3.3.3.2 and Section 3.6.1.6, shall be displayed to the user and show the network area under study. The map shall display thermal headroom for each cable segment and the peak power demand/output of each connection point for the selected feeders.

3.6.7.7 The user shall be able to delete mains and service cables that link connection points to a feeder, and draw new mains and service cables/lines to link them up to alternative feeders. The user shall be able to select the cable or overhead line types of new feeder segments from a list linked to standard types within the Configuration Database.

3.6.7.8 A list shall be displayed to the user showing the length and associated cost of each new segment of cable or overhead line and the number of joints that have been modified.

3.6.8 Installing New Assets

Switched Capacitors

3.6.8.1 Users shall be able to assess the impact of shunt connected capacitors, in switched capacitance stages, within LV and HV network areas.

3.6.8.2 The study of capacitors shall include the modelling of capacitance steps being switched under the control of a conventional AVC relay.

3.6.8.3 The solution assessment shall concern all connected HV feeders and use the customer load details, in particular power factor, and the EHV X/R ratio, as necessary, to estimate the impact of the capacitance on the voltage profile.

3.6.8.4 The user shall be able to place a switched capacitor component at a location along the feeder by clicking in the appropriate location both on a graph and a map (Section 3.6.1.6). A user-friendly methodology shall be implemented that enables the user to clearly ascertain the distance to the substation from each location, and place the capacitor accordingly.

3.6.8.5 The capacitor shall be indicated with an icon on the map in the appropriate location.

3.6.8.6 User-configurable design parameters shall include:

- Voltage set point;
- Capacitor value and step size; and
- Number of capacitor steps.

3.6.8.7   The software shall advise the user of the capacitor rating value required considering the expected real and reactive power flows.

Voltage Regulators

3.6.8.8   Users shall be able to assess the impact of voltage regulators within LV and HV network areas.

3.6.8.9   The solution assessment shall concern a particular feeder under study, which should be the individual feeder that features the worst voltage headroom levels.

3.6.8.10   A map, of the kind defined in Section 3.3.3.2 and Section 3.6.1.6, shall also be displayed to the user showing the feeder under study.

3.6.8.11   The user shall be able to place a voltage regulator component at a location along the feeder by clicking in the appropriate place both on a graph and on a map. A user-friendly methodology shall be implemented that enables the user to clearly ascertain the distance to the substation from each location, and place the voltage regulator accordingly.

3.6.8.12   The voltage regulator shall be indicated with an icon on the map in the appropriate location.

3.6.8.13   User-configurable design parameters shall include:

- Default ratio;
- AVC set point; and
- Tap range +/-%

3.6.8.14 The software shall evaluate whether the voltage regulator will be constrained by the Tap range +% or Tap range -% in attempting to reach the Voltage set point.

3.6.8.15 The user shall also be presented with the peak load at the location of the voltage regulator, to inform what rating such a component would require in practice.

3.6.9 Generators' Operating Mode

3.6.9.1 Users shall be able to assess the impact of generators operating against user entered fixed power factors within LV and HV network areas.

3.6.9.2 Users shall be able to assess the impact of generators operating in PV-mode within LV and HV network areas. Generators operating in PV-mode are controlled to adjust their reactive power output when the voltage strays beyond a permitted voltage band, in order to maintain the voltage within the upper and lower limits of that band.

3.6.9.3 The solution assessment shall concern a particular feeder under study, which should be the individual feeder that features the worst voltage headroom levels.

3.6.9.4 The user shall be able to select the generator that is to be operated in fixed power factor or PV-mode by clicking on a generator on the plot or the map. The generator selected shall be indicated with an icon on the map in the appropriate location.

3.6.9.5 The software shall have the ability for the user to assess control schemes intended to manage excessive voltage rise and configure design parameters as advised by the DNO, but would include:

- Upper and lower voltage limits;
- Voltage dead bands where no control is required; and
- Fixed power factor targets.

3.6.9.6   The software shall evaluate the reactive power output range and power factor range that the generator would be required to achieve in order to implement the design parameters defined by the user, and present this to enable the user to establish whether this is within the generator's capabilities.

3.6.10   Electrical Energy Storage (EES)

3.6.10.1 Users shall be able to assess the impact of EES systems connected to HV and LV network areas.

3.6.10.2 The assessment shall include the capability to model EES based on real and reactive export and import.

3.6.10.3 The assessments may be against fixed operating parameters to understand the impact against maximum and minimum demand or against a time-of-use half hourly profile of real and reactive import and export.

3.6.10.4 The software shall allow the user to configure the EES system by changing the rating values (real and reactive capability) and defining the output profiles.

3.6.11   Demand Side Response (DSR)

3.6.11.1 Users shall be able to assess the impact of DSR for customers connected to HV and LV network areas.

3.6.11.2 The costs of implementing HV and/or LV DSR shall be calculated based on a database of expected costs per megawatt (MW) for HV connected customers, and per household for LV connected customers.

High Voltage Connected Customers

3.6.11.3 The software shall be able to describe the amount of DSR required (MW) on a circuit and highlight to the designer the HV connected customers on relevant sections of network (i.e. connected downstream of the 'hot' asset).

3.6.11.4 For HV connected customers, the user shall be able to enter parameters to describe specific DSR contracts such as the amount of demand reduction or generation that is available.

3.6.11.5 For HV connected customers, the user shall be able to enter a demand reduction or generation profile which describes the expected response of a DSR customer, including any operational limitations on the maximum duration, based on response profiles.

Low Voltage Connected Customers

The software shall be able to describe the amount of DSR required on a circuit (% of customers) and highlight to the designer the LV customers on relevant sections of network (i.e. connected downstream of the 'hot' asset).

3.6.11.6 The software shall be able to apply time-of-use half hourly profiles, as a modification to existing household or LCT-based demand, to understand the impact of implementing DSR for domestic connections and the % uptake that would be required.

3.7 Scenario Forecasts

3.7.1.1 The software shall be able to simulate future scenarios of load growth and LCT uptake in a network area, by successively adjusting the demand level of consumers and their uptake of LCT technologies in a series of steps. Resulting headroom performance at each step shall then be assessed. The supplier may create a suitable algorithm within the software to achieve this, or utilise externally available tools.

3.7.1.2 Users shall be able to configure parameters to influence the specific nature of the future scenarios.

3.7.1.3 The user shall be able to select a network area and voltage level for analysis using the steps outlined in Section 3.3.3.6.

3.7.1.4 The software shall be configurable so that the default design assumptions are based on, for example, a ten-year forecast of load growth and LCT uptake. This would ensure designers develop networks which are suitable for the future.

3.7.2 Multi-year Load Growth and LCT Uptake

3.7.2.1 A tool shall be included which allows the user to carry out a multi-year forecast of load growth and LCT uptake across a selected network area, at both LV and HV level.

3.7.2.2 The algorithm shall take the following inputs:

3.7.2.2.1 A start and end year, specified by the user. This shall be bounded at the lower end by the present year, and shall range at least to the year 2050 at the upper end.

3.7.2.2.2 A percentage load growth applied to each consumer and each year between the start and end year. This could be a single percentage applied to all consumers and years, in which case the user should be able to specify percentage. An option could also be provided to utilise an external data set with yearly load growth projections.

3.7.2.2.3 A percentage probability of LCT ownership during each year between the start and end year, representing the percentage of consumers within a network area who own each type of LCT. This could be a single percentage for each LCT, applied to all consumers and years, in which case the user should be able to specify this percentage value. However, at least one option must also be presented to the user which instead utilises an external data set with yearly LCT ownership projections.

3.7.2.2.4 One or several parameters specified by the user that drive how the LCT uptake is spatially distributed between consumers near and far from the substation in the network area, such that the sensitivity to different spatial allocations can be tested.

3.7.2.3 For each year between the start and end year, the algorithm shall temporarily alter the network area in accordance with the relevant load growth and LCT ownership percentage. The specific algorithm is down to the discretion of the supplier. Each individual year may be considered in isolation, rather than build on the alterations to the network from the previous year.

3.7.2.4 For each yearly scenario, a headroom assessment (steady-state load flow) shall be performed as per Section 3.5.2. When all assessments are complete, the user shall be presented with:

- Summary headroom results during winter and summer for each year of the analysis;
- A count of each type of LCT present within the network area during each year; and
- The average load growth factor applied during each year

3.7.2.4.1 A measure of the amount of demand that is masked by distributed generation must be presented to the user.

3.7.2.4.2 A maximum and minimum load and generation for both summer and winter.

3.7.2.4.3 For HV analysis, results shall indicate load growth and LCT load attributable to LV, as well as masked demand due to generation on LV.

3.7.2.5 In collaboration with the DNO, the design shall include the ability to vary load growth and LCT ownership figures between different consumers based on demographics classifications.

3.7.2.6 LCTs that are represented in the LCT uptake scenario shall include EVs, HPs and PVs at LV, with a structure that enables further LCTs to be incorporated into the analysis.

3.7.2.7 The software shall also perform additional forms of assessments beyond load flow, such as heuristic rules for power quality. These will be clarified by the DNO.

3.7.3 LCT Uptake Within Threshold

3.7.3.1 A tool shall be included that identifies the number of LCTs that can be added to each feeder within a network area before a user-specified network performance threshold is reached. The purpose of this tool is to enable the user to estimate at what volume of installations a specific network is likely to start to operate near permissible limits.

3.7.3.2 The algorithm shall take the following inputs:

3.7.3.2.1 The type and definition of the LCT to be added, with sufficient detail that the LCT can be analysed as part of a headroom assessment. LCTs that are represented in the LCT uptake scenario shall include EVs, HPs and PVs at LV, with a structure that enables further LCTs to be incorporated into the analysis.

3.7.3.2.2 The network performance thresholds that will define the point at which no further LCTs can be added to the network. Standard headroom thresholds shall be included: % voltage drop, % voltage rise, % cable utilisation and % transformer utilisation.

3.7.3.2.3 One or several parameters specified by the user that drive how the LCT uptake is spatially distributed between consumers near and far from the substation in the network area, such that the sensitivity to different spatial allocations can be tested.

3.7.3.3 The algorithm shall identify the largest count of the chosen LCT that can be added to each feeder within the network area before the chosen threshold level is reached. This shall be obtained by repeated headroom assessments, where LCTs are distributed spatially between consumers with the network area as per Section 3.7.2.3.

3.7.3.4 As an output, the user shall be presented with the permissible number of LCTs on each feeder along with other information chosen by the DNO, such as the number of connection points on the feeder.

3.8 Policy Compliance Search

3.8.1.1 A search tool shall be included in the software that is capable of identifying relevant clauses from the DNO's policies, planning guidance, specifications or other documentation stored in the network database, based on search terms as well as metadata tags.

3.8.1.2 A semi-automated process shall be provided that separates out individual clauses from the DNO's policies, planning guidance, specifications or other documentation, such that these individual clauses can be displayed in isolation, be searchable, and be linked to the source document.

3.8.1.3 During the course of a network assessment this tool shall present the user with a list of clauses tailored specifically to the type of network assessment that is carried out.

3.8.1.3.1 Specifics of which clauses are to be related to a particular type of network assessment shall be agreed with the DNO, and will also depend on individual circumstances of that assessment such as the type of load that is being connected as part of a new connections request.

3.8.1.3.2 Functionality shall be included such that the user can influence which topics of clauses are displayed as part of particular workstreams (Section 3.4), for example by selecting/de-selecting topics via tick boxes in the user interface.

3.8.1.4 The user shall similarly be able to access clauses and source files from within the Policies main menu section (Section 3.3.2.1.3):

3.8.1.4.1 It shall be possible for the user to find relevant clauses by entering user-defined keywords in a search engine-style interface.

3.8.1.4.2 A means shall be included for the user to browse such clauses and source files organised by DNO-defined categories.

3.8.1.5 The user shall be able to access the individual clauses from within the search results, as well as opt to open up the original full-length source document in digital format via a direct link.

3.9 Novel Functionality to be Developed

3.9.1.1 This section defines the functionality, and intended direction, of subsets of the tool to be innovatively developed with a DNO or collaboration of DNOs.

3.9.1.2 Real-Time Thermal Ratings (RTTR) for cables, lines and transformers. Once datasets with monitored data of the capacity of individual assets become accessible, these can be incorporated within the network assessments as dynamic equipment ratings that vary during seasons and the course of a day. Data from monitoring or third-party sources can also be used to allow a designer to apply a bespoke rating for an asset, based on additional information such as topology and weather patterns.

3.9.1.3 Sophisticated models of consumer and generator behaviours that are based on demographics, location or other differentiating factors. As reliable data sets become

available, it could be possible to link consumer demand profiles to household size or other demographic classification, or similarly link generator output profiles to meteorological factors of the region. Sufficient flexibility is needed in the use of customer models to allow links to be formed to external datasets that describe these classifications.

3.9.1.4 Probabilistic network headroom assessments that account for the stochastic behaviour of consumers and generators at LV in particular, thus providing a more accurate account of diversity and actual headroom on the network over time. This may for example take the shape of Monte Carlo simulations of power levels at connection points during different times of the day, as is often used for academic research purposes.

3.9.1.5 Network classifications with associated acceptable LCT penetration rates. As reliable data sets become available, parameters pertaining to an individual network's design and characteristics could be used to classify it according to SGF WS3 classifications or other methodologies, with an associated acceptable LCT penetration rate. LCT installation records could be used to highlight to the DNO when the limit is approached or exceeded, to instigate the first step of mitigating action such as monitoring. Such rules would be implemented as heuristics to link LCT ownership with network characteristics.

3.9.1.6 Cumulative harmonics issues on a network with associated LCT installation limits. A methodology could be developed which highlights a likely existing cumulative harmonics issue on a network, to flag a likely need to monitor the network area and potentially take mitigating steps. This could be based on a count of non-linear loads or LCTs within the network area, from records of previous connection requests from DNO databases and/or on assumptions about appliance or LCT ownership based on consumer demographics classifications. Alternatively, if data sets are available, a network could be classified as in Section 3.9.1.5 with an associated limit of LCT installations.

3.9.1.7 Live network measurements or events that present actual conditions on the network. As DNOs implement monitoring capabilities at substations and feeder points across networks, this data could be collated within the software and used not only for RTTR (Section 3.9.1.2) but also to adjust network assessment model results or highlight network areas where design interventions may be required.

3.9.1.8 Real data measurement for HV feeders can be used to derive load profiles, which can be used to perform HV time-of-use assessments. This would allow the tool to create voltage profiles for all LV substations.

3.9.1.9 Use of smart meters. DNOs having access to smart meter data could present opportunities for more accurate network models. The software tool should have the flexibility to allow the use of smart meter data on individual connection points when this data becomes available.

3.9.1.10 Models of smart / non-smart control of devices on LV and HV networks, and their effects on network performance. In future this may include coordinated control algorithms by systems such as the Grand Unified Scheme (GUS) implemented as part of the CLNR project. The time-of-use models used by the software could be exported and used as inputs into control scheme state estimators.

3.9.1.11 Development of the Sensitivity Factors proof of concept. Sensitivity factors are a mechanism that allows network performance to be characterised by its resistance to changes in power flow. This could be developed as an alternative to performing routine load flow assessments and could improve the speed of generating assessment results.

4 Non-Functional Requirements

For the purposes of production of this specification, and not intended to bias the design approach, non-functional requirements are split into the following sections:

1) Hardware
2) Security
3) Performance
4) Interoperability
5) Users
6) Usability
7) Reliability
8) Support
9) Installation
10) Maintenance

4.1 Hardware

4.1.1.1 The DNO shall provide a central server for the software that meets their internal security specifications, to host the core software and database as per Section 3.1.1.1. Where the DNO already has a server specification for network database purposes, this may form a starting point for specifications.

4.1.1.2 The DNO shall also provide a web server for a web-based user interface as per Section 3.1.1.2.

4.1.1.3 The supplier and DNO will need to define appropriate access privileges (read only, read write) and how this is tested and agreed.

4.1.1.4 Guidance is to be provided by the software supplier that defines the technical requirements of these servers.

4.1.1.5 As needed, the supplier shall have appropriate remote access to both servers in Section 4.1.1.1 and 4.1.1.2 for administration and configuration purposes.

4.1.1.6 The supplier shall be responsible for maintaining a suitably reliable connection to the DNO's network databases and other data repositories, for the purposes of keeping the software database up-to-date. A method statement shall be provided that describes how this will be implemented, including failure procedures.

4.2 Security

4.2.1.1 As needed, the supplier shall take formal responsibility for the integrity of the DNO's source data in relation to the link to the software in Section 4.1.1.6, and shall provide methodologies for how this will be achieved.

4.2.1.2 The supplier shall liaise with the DNO to provide a statement on how adequate data protection steps will be taken within the software to comply with any relevant legislation.

4.3 Performance

4.3.1.1 The supplier shall produce a set of software performance targets, to align with the DNOs requirements, that must include:

4.3.1.1.1 Maximum time taken for key functionalities and in particular network assessments (Section 3.5).

4.3.1.1.2 Minimum availability of key functionalities of the software, including a plan for how this may be improved during subsequent years.

4.4 Interoperability

4.4.1.1 The software shall be designed to enable flexible and robust interoperability with external software tools as required, as per Section 3.1.2.

4.4.1.2   The supplier shall liaise with the DNO on developing real-time interfaces with existing network datasets. The options are:

- Develop a full read and write interface between the software and the network dataset;
- Periodically copy the full network dataset to a separate database and store all assessment results to the software's Configuration Database. The interface to the DNO network database would be read only.

4.4.1.3   The software shall be designed to enable Microsoft Office products to work seamlessly.

4.5 Users

4.5.1.1 The software shall be capable of supporting multiple concurrent users to an extent that meets the operating requirements of the DNO.

4.5.1.2 Load testing methods shall be applied to ensure the system is capable of supporting the required number of users without reducing performance below acceptable limits.

4.5.1.3 Queuing systems may be implemented within the software if needed that put assessment requirements of multiple users on hold until such time that sufficient resource is available, in particular where access to external tools in use by the software may be limited.

4.5.1.4 Consideration shall be given to ensure that when an individual user is working in a particular part of the software, or on a particular portion of network, the appropriate software areas are 'locked out' to other users to ensure there is no conflict.

4.5.1.5 Different user roles shall be defined, with appropriate authorization levels and privileges to run assessments and make changes within the software, to suit the workflows and operational requirements of the DNO. User logins with user names and passwords shall be implemented to facilitate this. Links to the corporate active directory shall be used to quickly establish credentials for internal staff.

4.5.1.6 A super-admin user role shall be defined with the capability of managing user accounts.

4.6 Reliability

4.6.1.1 Error handling and robustness shall be ensured by logging the occurrence of an error, displaying an appropriate message to the user, and returning the software to a stable state as needed.

4.6.1.2 During beta-testing, users shall be able to report bugs and other concerns.

4.6.1.3 Software administrators shall be able to access error log files and user bug reports in order to investigate and resolve the underlying issues.

4.6.1.4 All user input forms within the software shall have appropriate validation added. For example, it should only be possible to enter numeric values into fields which require a numeric value. Invalid entries shall be highlighted and an informative message displayed to the user.

4.6.1.5 The supplier shall liaise with the DNO to design and implement an appropriate backup and disaster recovery strategy, driven by factors such as desired frequency of backups and acceptable downtime. Backup and recovery protocols already in place within the DNO's own network databases should influence the approach taken.

4.6.1.6 Where desired by the DNO, a primary / standby architecture shall be implemented to allow for failover in the event of a database server failure. This will consist of a physical standby database on a separate server to that defined in Section 4.1.1.1, which should always be available and up to date, to be used in the case of the primary server failing. A similar principle would be used for the web server defined in Section 4.1.1.2.

4.6.1.7 The supplier shall also provide any further details on how system reliability and performance will be protected, which may for example include health monitoring tools that identify long-running database operations, or regular verification test to ensure data transferred from the DNO's databases have been transferred correctly to the software.

4.7 Support

4.7.1.1 User documentation will be provided in the form of help pages and a pdf user guide, both accessible to users via the software interface.

4.7.1.2 A permanent mechanism shall be put in place that enables users to report bugs and issues online, via email or via telephone, categorised by severity.

4.7.1.3 A service level agreement shall be created by the supplier and approved by the DNO that states requirements on response times to categories of user-reported issues depending on severity, and implements a procedure for prioritisation of issues.

4.7.1.4 Training tools and/or in-person sessions shall be designed and agreed with the DNO, and provided by the supplier.

4.8 Maintenance

4.8.1.1 A release plan shall be designed and implemented by the supplier, which makes regular updates to the DNO's system to implement bug fixes as well as new features where these have been formalised by a separate agreement. The release schedule shall be agreed with the DNO through the prioritisation of bug fixes and new features.

4.8.1.2 Updates shall be implemented outside of office hours to minimise downtime.

5 Development Overview

A prototype software tool has been produced as part of the CLNR project, as referred to in Section 1, that features a proportion of the functionality described in this specification. Areas of functionality that were not demonstrated as part of that work are highlighted here, with an indication of the development and deployment work that would be required to procure the software specified in this document.

5.1 Innovation

Further novel work is required to deploy the prototype concept into a DNO's BAU practices. Significant innovation is required primarily in order to:

1) Reliably link asset databases to the assessment tools; and
2) Stitch in emerging learning from innovation projects.

Within the context of the specification in this document, this novel work refers to the delivery of the following main functionalities:

5.1.1 Links to DNO Data Sets

The software prototype imported a sample set of Northern Powergrid's LV and HV networks as a one-off, off-line, one-way, and partly manual process, demonstrating the capability to handle asset data in several formats and illustrating ways in which such data can be 'cleaned' for assessment purposes.

For a BAU product, this process must be automated and capable of repeated updates. It must also interface with any necessary DNO data repositories, such as SCADA tools and cost books. Innovation is required to enable:

- **Robust link:** A robust live link with the range of necessary DNO databases, that ensures the software regularly receives updated data whilst protecting the integrity of the original data sets, with failure methods and strategies in the event that the link is unavailable.
- **Automated data processing:** Automated translating processes from DNO asset data into CIM or other data formats used in the software, including resolution of connectivity problems and errors.
- **Writing data back to DNO:** Ability to upload selected changes to the network from the software to the original DNO databases.

5.1.2 Incorporating Emerging Knowledge

Section 3.9 describes a number of novel functionalities that rely on innovation in network data sets and knowledge. Such functionalities have not been incorporated into the prototype as they require robust methodologies to be available, whether through deployment of monitoring equipment to gather the necessary data, or through development of new modelling and interpretation tools.

In broad terms, innovation is required in conjunction with the DNO in the following areas:

- **Data sets**: Incorporating RTTR, demographics and geographic information driving consumer/generator behaviour, live network measurements or events, SCADA data for HV feeders used to derive load profiles, and use of smart meter data at individual connection points.
- **Modelling**: Probabilistic network headroom assessments, and models of smart / non-smart control of devices on LV and HV networks.
- **Data interpretation**: Network classifications with associated acceptable LCT penetration rates, cumulative harmonics issues on a network with associated LCT installation limits, and Sensitivity Factors indicating where a network can accommodate load or generation.

5.1.3 Additional Functionality in Novel Modules

The software prototype demonstrated a range of novel functionalities in particular with respect to enabling the user to analyse LCTs, identify and test appropriate solutions to headroom problems, and review relevant policy documentation. Some such modules require additional innovation in order to become fully BAU ready as per this specification. Examples include:

- **Generator profiles:** Like consumers, generator outputs on LV networks are characterised by an element of diversity that should be accounted for in network assessments. Also, there is a requirement to model generators when connected using non-firm arrangement, such as PV mode or other variable power factor scheme. A statistical methodology is required to derive appropriate diversified profiles, in a similar manner to ACE49.
- **Policy clauses:** Depending on the extent of relevant policy documentation held by the DNO, an automated process may be required to extract individual clauses from such files. In the prototype this process was manual.

5.2 Expansion

A set of functionalities are also required in addition to those demonstrated by the prototype, where innovative activity is substantially smaller. The software tool is intended to provide consistency in design practices, and therefore it must include functions to replicate many other tools across a DNO business. Here, the focus is on:

1) Incorporating functionality that is already in use by other BAU tools or types of software; or
2) Expanding methodologies of the prototype to cover a wider range of cases.

In brief, this encompasses areas and examples such as:

- **Non-functional requirements:** Scaling up to accommodate the whole licence area, completing network assessments within suitable operational time scales whilst accommodating simultaneous multiple users, applying user logins and user privileges, logging and addressing bugs, backup and recovery procedures, and user documentation.
- **Components and control strategies:** In particular AVC strategies such as Line Drop Compensation, and fuses, link boxes and circuit breakers.
- **Saving and accessing data:** Saving and re-loading instances of a workflow in-progress, user access to external network tool input/output files, and enabling import of data files from external software in order to run assessment on those.
- **Data storage:** Storing non-technical DNO data such as cost books and scheme papers, and enabling 'layers' of network data such as approved / commissioned / or awaiting build designs.
- **User interface:** Viewing HV networks as line diagrams, viewing 'layers' of network data such as any commissioned but not yet built designs, and creating a calculator feature.
- **Automated assessments:** Regular assessments to identify networks that require attention, and regular LCT and load growth scenario forecasts to trigger appropriate action.
- **Headroom assessment features:** Unbalanced load flow assessments, analysis of losses on a feeder level basis, expanding the use of 'load allocation' of measured data across feeders at HV and LV.
- **Additional network assessments:** applying several types of assessments in succession to a given network area, including security of supply (contingency), reliability, fault level and fuse requirements, disturbing loads and LCTs, and transients and stability.

- **Additional headroom solutions:** implementing conventional solution workflows as part of the detailed solutions assessment, and additional emerging ones such as generators in PV-mode.

5.3 Refinement

Finally, the prototype is not a fully developed piece of software, but is built on the principles of proof-of-concept. As such, whilst functionalities have been demonstrated, they may require further adjustment or rearrangement. This type of refinement includes:

- Fine-tuning displays, results presentation, and user editing abilities within the user interface;
- Adding and adjusting workflow processes as needed;
- Refining the representation of assets, consumers, and generators in the software database;
- Incorporating LCT uptake scenarios into HV assessments;
- Deploying combinations of solutions when assessing solutions in detail; and
- Developing the search terms used to identify relevant policy clauses during assessments.

Customer-Led Network Revolution

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