REPORT

HV Network Data Specification

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1. Background and Introduction

The Road to Power project aims to develop a proof-of-concept tool for National Grid Electricity Distribution (NGED) to enable their customers wanting to connect a site at HV (11kV) to be provided with options for connection types. The innovation this tool delivers is the inclusion of assessments for flexible connections that are offered by NGED.

The primary purpose of this phase of the project is to develop and then implement in a proof of concept, the logic required for a flexible connection assessment to be made.

To enable a connections assessment to take place, the tool must have an accurate model of the network available. This includes asset information such as conductor lengths and types, topography of the whole network and network loading. In a full connections tool, in use by customers, inconsistent or incorrect data could have repercussions for NGED, so cleansed and reviewed network data are a priority.

Within the concept tool, NGED Common Information Model (CIM) data has been used to model a network in South Wales.

For the purposes of the proof-of-concept tool and the time constraints placed upon the project by the nature of the SIF Alpha timeline, the concept network does not include connectivity. Loads for this network within the proof-of-concept tool have been generated to optimise the demonstrability of the innovative functions associated with the Road to Power project: temporary and non-standard connections.

This document is primarily to be used as a basis for the minimum network data requirements expected for the full development of an HV connections tool.

2. Definitions

This section is used to define both abbreviations and significant terminology for the project. This page will be updated continuously during the project until the final version of the tool specification is decided at project closedown.

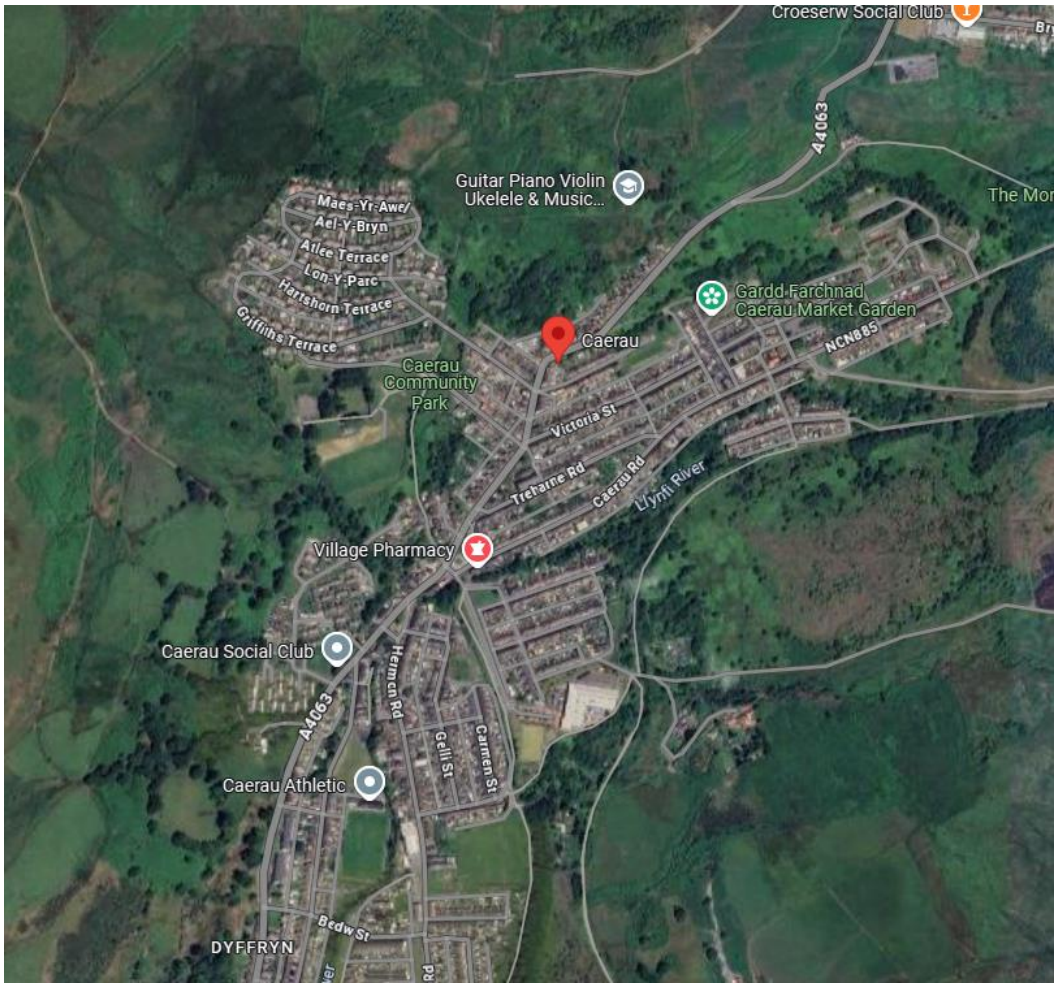
ANM	Active Network Management, in constrained areas of the network these systems will be implemented to allow customer connections to be made that would otherwise require prohibitively costly network reinforcement, or to accelerate connections where reinforcement has a long lead time. For the purposes of implementing ANM, the network is divided into ANM Zones, each Zone comprising a Grid Supply Point (GSP) or GSP group depending on network complexity.
CIM	Common Information Model
Curtailable Connection	A connection within an ANM zone that has been provided with a curtailment assessment.
Debut	A Debut assessment is a power systems assessment tool that analyses load flows on networks.
GSP	Grid Supply Point
Time Profiled Standard Connection	A connection with a variable maximum demand based on available network capacity.
HV	For this specification, HV refers to the 11 kV network.
NGED	National Grid Electricity Distribution

3. CIM Data Overview

EA Technology's load flow assessment tool, Debut, uses real network data to assess new connections at any point on a network. This section provides a high-level overview of the NGED CIM network data utilised within this proof-of-concept tool.

CIM data was retrieved from NGED's website.[1]

The network chosen to be modelled originated from a primary substation northwest of the town of Caerau in Maesteg, Wales.



The primary substation is visible in the top right-hand corner of this image. This primary has five feeders, apparent in the CIM data, three of which were modelled with example loads. The three feeders with loads ran south, two southeast and one southwest of the primary.

This CIM data did not provide loading for the network. For the purposes of this project, the loadings on the feeders were generated utilising assumptions based on the capacity of the LV transformers on the network, the number of connected customers and the lengths of the feeders. The loadings generated do not accurately reflect real world loadings.

[1]National Grid Common Information Model: https://www.nationalgrid.co.uk/our-network/energy-data-hub/common-information-model

4. Data Requirements

This section covers the requirements for the network asset data and the network load data. These are covered separately, however in some cases they will be provided in the same data set. Network asset data refers to physical assets like cables and transformers and the topology of the network, while network load data refers to the demand profiles of the loads on the network. In the case of HV networks, this is the load profile at the HV/LV transformers.

Some of the data is required for the load flow assessment and some of the data is required for the visualisation of the network within the tool. Within the Road to Power project, the network asset data is from CIM data and the loading data has been generated to demonstrate the concepts of the non-standard connections.

In the final iteration of the tool the load data on each primary substation network will come from either modelled or monitored data that NGED will provide and refresh on a regular basis.

4.1 Network asset data

This section covers the minimum network asset data required and reviews the suitability of the chosen CIM data for each aspect of the data. In general, the network asset data is mostly available within the data set, however, extracting and cleansing the data for a discrete section of the network requires the same set up as doing the same for the whole network.

Reviewing and ensuring each part of the network's data is correct is a manual task, which is why only three feeders for a single primary were used in the proof-of-concept tool.

4.1.1 Network connectivity

To run a network load flow assessment the network model must be connected electrically within the model. This was achieved by matching the nodes within the asset data to ensure continuity throughout the model. This was done manually and was a labour-intensive task as automating the connectivity nodes alignment required more effort than a manual approach. In a full connections tool model, automating the connectivity model will be a base requirement as there are millions of nodes to connect.

If this task cannot be automated for CIM data then another source of network data may be required.

4.1.2 Conductor Data

To run a network load assessment various asset properties are required.

Conductor information, such as the following, is required to run the load flow assessment:

- Conductor type
- Conductor size
- Conductor length
- Is it overhead line or cable
- Operating phase/neutral resistance per metre
- Operating phase/neutral reactance per metre
- Fault phase/neutral resistance per metre
- Fault phase/neutral reactance per metre
- Conductor rating

Some, but not all, of this information was available within the CIM data. Utilising a comprehensive dictionary of conductor types would enable the required asset properties to be filled in where missing. However, within the CIM data, some line segments, where the cable type data was stored, contained multiple types of conductors

without providing the lengths of the different conductors within the segment. In these cases, a clear differentiation in lengths of the conductors will be required to provide an accurate assessment.

Missing assets on the network jeopardise the ability of the load flow assessment tool to provide accurate information regarding a user's ability to connect to the network. Similarly, incorrect asset data will return inaccurate network capacity data and could impact whether a user receives a correct connection assessment.

4.1.3 Transformer data

For upload into the Debut program, the distribution transformer data functions closer to a load. The CIM data provides some information however it is not considered necessary if the LV transformer load information is available.

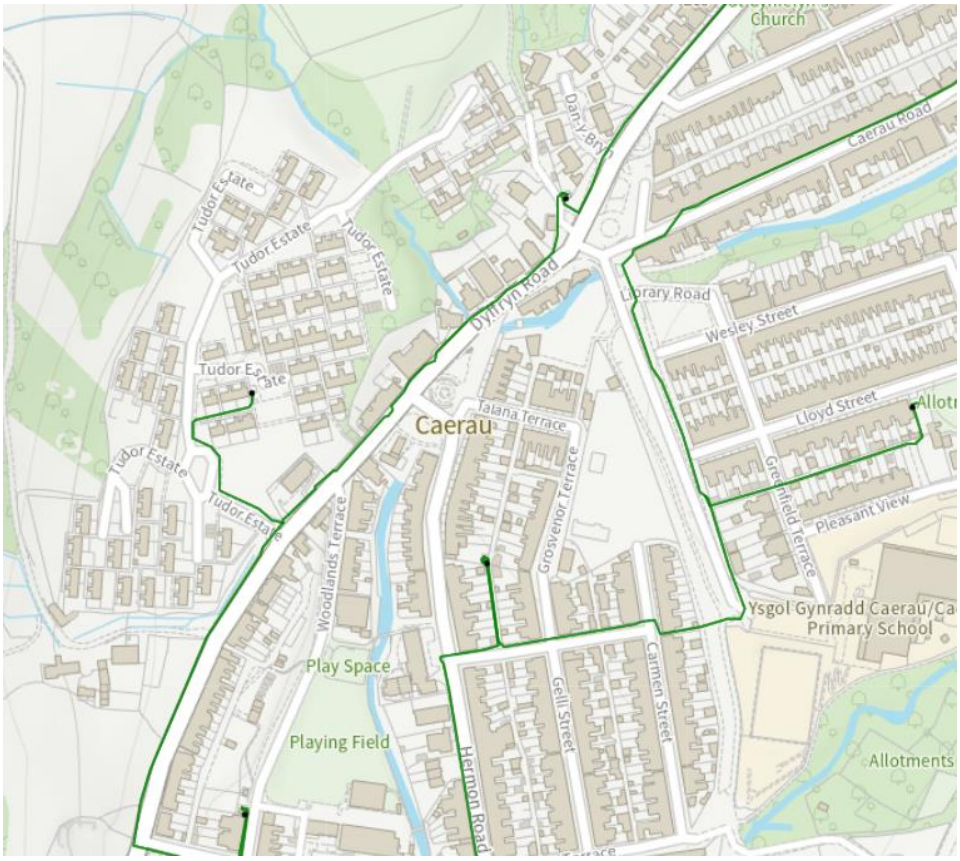
The load data required is covered in the Network Load Data section.

4.1.4 Locational data

In a full deployment of an HV connections tool, all network data must be cleansed and reviewed to ensure the asset locations are accurate. Within the CIM data utilised for this concept tool there were clear inaccuracies regarding some locations of assets.

The location data is generally separate from the data used within the load flow assessment. For example, the length of a conductor recorded in the asset data is not derived from the geometry displayed within the tool. This means that the locational data accuracy will not impact the connections assessment. However, ensuring the locations are accurate is important for user comprehensibility and to enable reliable connection requests.

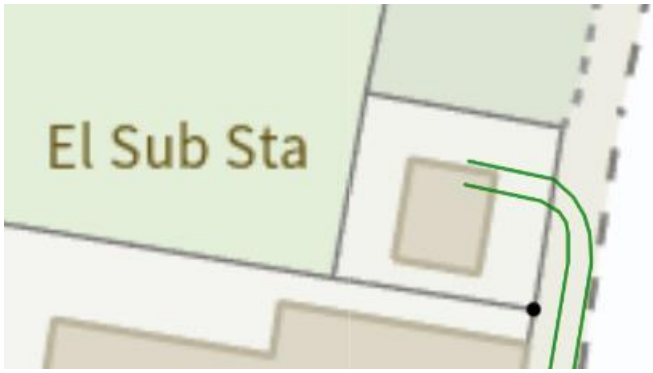
Three feeders from the same primary have been taken from the CIM data and reviewed in more detail. The location asset data for conductors was provided in LineString and MultiLineString types while transformers had Point types providing their locations. These data points were plotted within the tool to test the suitability of the locational information within the CIM data.



The majority of lines on the chosen feeders aligned with streets and other geographical marker which would make sense for cables and overhead lines to be located around. Similarly, the locations of ground mounted transformers aligned with places on the map marked as “Electricity Substations”. This was positive for the use of the geographical data from the CIM data, however there were some anomalies which are detailed here.

In some cases, the MultiLineString data showed conductor paths that were unlikely to be realistic. In these cases, for the proof-of-concept, they have either been deleted or rectified where the fix is straightforward. In a wider tool rollout this is an example of an issue where manual review of data may be required to rectify the mapping to ensure a smooth user experience.

For the purposes of this project, near accurate location data is acceptable as the information is not rely upon. Within the CIM data there is substation location data available, based on the corners of the site. To make a more accurate map, the centroid of the substation is preferrable to be used however this may not align with the cable terminations.



It may also be suitable to use the location of the connectivity node that connects the incoming cables and the substation. The data that provides the location of the substation can be adjusted in the final tool.

4.1.5 Additional network components to consider

This concept tool simplifies some characteristics of the network to deliver a functional tool within the project delivery period.

This tool assumes there is no HV connected generation on any of the feeders reviewed. This is a simplification for the purposes of the Alpha phase for the Road to Power project, however it is likely something that should be considered in the fully developed tool.

4.2 Network load data

This section describes requirements related to network loads that enable the development of 48 half hourly demands for the assessment. The key addition from other connection tools is the assessment is based on the capacity of the network across those 48 half hour periods.

4.2.1 Existing network loading data

The challenge with existing load data, for the distribution substations, is that it is generally not temporal. For each distribution substation on their network, NGED provides a maximum demand for both day and night. This information is publicly available on their Connect Data portal[2]. However, these maximums are the maximum recorded at or modelled for that substation and do not provide any further context to the exact time that they might occur.

48 half hour data for the distribution substations in the network chosen were not available. Even if monitored distribution substation data was available, the 48 half hourly substation demand data would only represent one day.

For the Road to Power project, a key aspect is how the network capacity varies across months to provide the user with some insight as to when their capacity may be constrained. Therefore, network capacity must demonstrate some variability across months to prove the concept.

Within this tool the network loading is varied based on season, with the winter network demand being scaled down to simulate increased network capacity during the summer months.

4.2.2 Existing asset utilisation data

Within the CIM data there are some indications of the existing capacity of the conductors, however there are clear inaccuracies (some cables have their available capacities as a placeholder 9999). Within the concept tool, the feeders have been followed to their completion and the available capacity downstream has been limited to at least the capacity upstream. This ensures that a user cannot attempt to connect a site downstream of a constraint on the network.

4.2.3 Next steps regarding load data to enable assessment of 48 half hourly loads

The tool extrapolates the loading for each half hour period for each season by using the maximum demand on the network to fit an example feeder demand profile. Moving forward this approach is unlikely to be suitable.

To provide a comprehensive assessment, half hourly demand data for each distribution substation would be required however, some simplification of the load data on the network is required. It is not sensible to assume half hour data for each day for every substation can be used, especially as the user is unlikely to calculate their own half hour data for every day of the year. For each distribution substation this would be 17,520 half hour demands and the same would be required for the customer.

This is not a practical ask for input by the customer and an extremely computationally heavy load for the power flow assessment.

[2] Distribution Substations - Dataset - Connected Data Portal | National Grid - https://connecteddata.nationalgrid.co.uk/dataset/distribution-substations

Table 1: Comparison of volume of data required for different demand sampling frequencies

Network Demand Data Provided	Number of Half Hour Demand Data Points	Comment
Maximum demand in a year	1	Used in current connection assessment tools for standard connections. Could be extrapolated to provide estimated demands for 48 half hour periods if a load profile is available.
One set of 48 half hour demands	48	Can be scaled to provide winter and summer variability. Reliability will depend on the 48 half hour dataset chosen.
48 half hour demands for winter and summer	96	This option has been used for this proof-of-concept tool for demonstration purposes. The 48 half hourly demands were created for winter and they were scaled down for the summer. Summer: April -September Winter: October-March
48 half hour demands for each month of the year	576	Likely to be based on a weekday profile to provide highest half hourly demands in each month. Valuable data granularity relating to sites that may have large demand variation between months, e.g. construction sites with varying work patterns over a given year.
48 half hour demands for each month of the year, with profiles for weekdays and weekends	1,152	Provides greater detail for connections with large variability between weekdays and weekends and variation between months. Data requirements likely to be too large for this tool.
48 half hour demands for each day of the year	17,520	If based on monitored data at the distribution substation then data reliability likely to be high. Data processing and storage requirements unsuitable for this tool.

As this tool is not expected to provide a firm connection offer there will still be a need for a connection engineer to assess any non-standard connection agreements drafted by the tool. Further discussion with NGED connections policy, network data and connections design teams will be required to decide on the correct granularity of the data for assessment.

For the purposes of informing a user in the early connections process, a winter and summer profile is likely to be suitable for most purposes. The Road to Power concept tool asks for monthly demand peaks and the time they are likely to occur, for example during shifts, so at maximum the most that would be required is monthly network capacities.

If the tool was required to do a full assessment for a curtailable connection, then each half hour period for the whole year would have to be assessed for the likelihood of curtailment.

In a full deployment scenario, it is likely that the tool will provide an indication of the curtailment required for a customer to connect and then an NGED connections engineer will do a full curtailment assessment.

4.2.4 Next steps regarding the load flow assessment

The outputs from the Debut assessment must also be reconfigured to efficiently deliver the right data to make the assessment. At present the Debut outputs do not automatically surface the results of each half hour assessment for each asset on the network, to reduce the amount of data transfer in each pipeline when the only half hour period of interest was the one with the highest demand.

Within the Road to Power tool, and to enable the assessment of flexible connection, each half hour assessment must be passed to the front end of the tool. If seasonality (winter/summer) or monthly differences are to be fully included in the assessment, then this increases the volume of data being passed through the pipelines from 48 half hours to 96 half hours (two days of the year) or 576 (12 days during the year) half hours. It is recognised that this is a significant increase in the volume of data that must be handled by the tool.

For the proof-of-concept the load data has been simplified and calculated a winter and summer difference. However, this simplification is likely to be unsuitable for the more detailed assessments required for the curtailable connection agreements. Even using a daily profile from each month of the year will not show the nuances of weekday and weekend demand variations.

The policy associated with the forms of non-standard connections within this tool must to be updated in order to provide a direction for encompassing the required amount of detail needed for the connection load assessments.