Spatial Modelling –Electricity Supply Areas

Since 2016, Western Power Distribution have developed an approach to geographically map areas of our network. These are defined an **Electricity Supply Areas (ESA).** This document outlines why they are used and a brief process of how they are created. In summary, each Electricity Supply Area represents a geographic area which shares the same upstream network infrastructure.

Purpose of Electricity Supply Areas

As part of the transition towards being a Distribution System Operator (DSO), it is necessary to be able to translate between datasets which describe the distribution network assets and geographic datasets for various modelling purposes. WPD is using Electricity Supply Areas in the following DSO activities:

- **Distribution Future Energy Scenarios** – used to spatially allocate demand and generation growth to the most likely point of connection to the distribution network. The level of ESAs used in DFES studies are determined by the level of electrical analysis that is undertaken.
- **Network capacity map** – used as a layer on the network capacity map to demonstrate the geographic area supplied by a Primary substation, Bulk Supply Point or Grid Supply Point.
- **Network flexibility map** – used to visualise the Constraint Management Zones where WPD procures flexibility services. A postcode to Primary substation lookup is also used as part of the network flexibility map.

ESA Creation Process

Input Data

The first step of the process is getting asset and geographic data. To obtain asset information, a snapshot of the network reference hierarchy is taken for every substation from WPD's asset record database. This information is mapped onto WPD's mapping software, which is the most accurate data source of substation geographic locations. These two datasets are combined and used as an input to GIS software to create a point layer of all substations on the distribution network. A map of the DNO licence area boundaries is also used, provided by WPD's mapping team.

Data Verification

The network running arrangement can change regularly on the distribution network, For example if a normal open point on an 11kV ring is moved as part of routine network assessment, the distribution substation will consequently be supplied from a different primary substation. These changes are reflected by the network reference hierarchy associated to each substation in WPD's asset record database. To account for these changes and for other identified network connectivity errors the ESA process is updated yearly.

The sheer amount of distribution substation becomes impractical to identify errors on a case by case basis. An automated statistical approach is used to identify any obvious error in the substation network reference hierarchy, which is outlined below:

1. The distance between each distribution substation and the upstream primary substation is calculated. When plotted, this data resembles the map shown in Figure 1;

Figure 1 - Line to hub diagram used for Data verification (starburst)

2. For each primary substation, the mean distance to a distribution substation was calculated and its corresponding standard deviation;
3. This information was used to normalise the distance of each distribution substation relative to the average distance for the primary substation. This is to reflect the difference between urban and rural network topologies.
4. The normalised distance between each distribution substation and its upstream primary is used to calculate a Z-score, which represents if a distribution substation is abnormally far away from the primary substation, relative to all other distribution substations fed from that primary. A summary of Z-scores for all distribution substation in each licence area is shown in Figure 2.

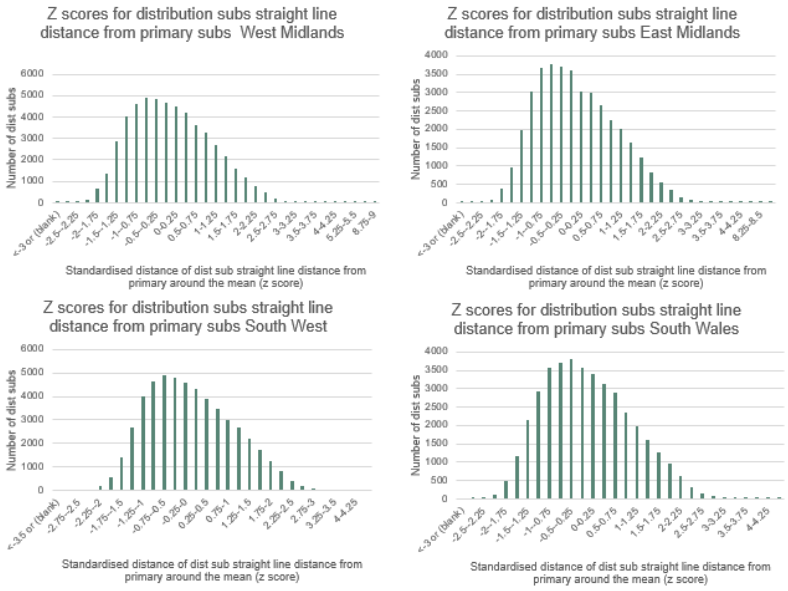

Figure 2 – Z-scores per primary categorised by licence area

5. Where a distribution substation is found to be abnormally far from the upstream primary substation, these are then inspected visually to see if there are any errors in the network reference hierarchy.

Creating Geographic Polygons

To produce the Electricity Supply Areas, the input datasets are combined and filtered to all distribution substations (HV/LV) within a licence area. An algorithm is run to create Voronoi polygons for each distribution substation. Each polygon represents an area which has a common distribution substation as the closest point of connection to the HV network. Figure 3 visually demonstrates how each distribution substation has a small Voronoi polygon.

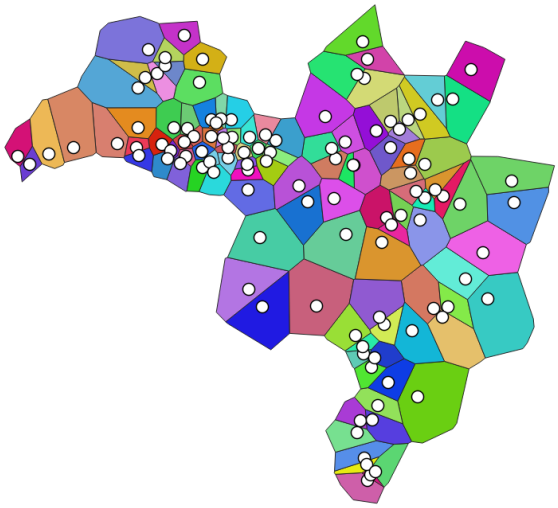

Figure 3 - Bingham primary (East Midlands) Voronoi polygons

This methodology provides an accurate estimate of the geographic footprint of each distribution substation. After testing various input datasets, it was determined that determining Voronoi polygons at a distribution substation level provides a sufficient level of accuracy for the computational effort.

Licence Area boundary processing

The WPD licence area boundary includes several islands that are not connected to the main distribution network. A consequence of using distribution substations to create Voronoi polygons is that islands which do not take supplies from the distribution network artificially alter the polygons of any surrounding islands. To avoid those being represented in ESA process all islands without a distribution substation were removed, as shown by the Isles of Scilly before and after processing in Figure 4. This also removes smaller islands off South Wales, the Isle of Lundy and others. If in the future islands with no supply get connected they will be represented in the map.

Figure 4 - Isles of Scilly before and after processing

Creating Network ESAs at different voltage levels

As every distribution substation in WPD's asset record database contains a hierarchy of the upstream network infrastructure, the distribution Voronoi polygon dataset can be dissolved up to different levels

of the network reference hierarchy, as shown for the South Wales licence area in Figure 5. These polygons are called **Network ESAs**. After data validation, these polygons are published on our website.

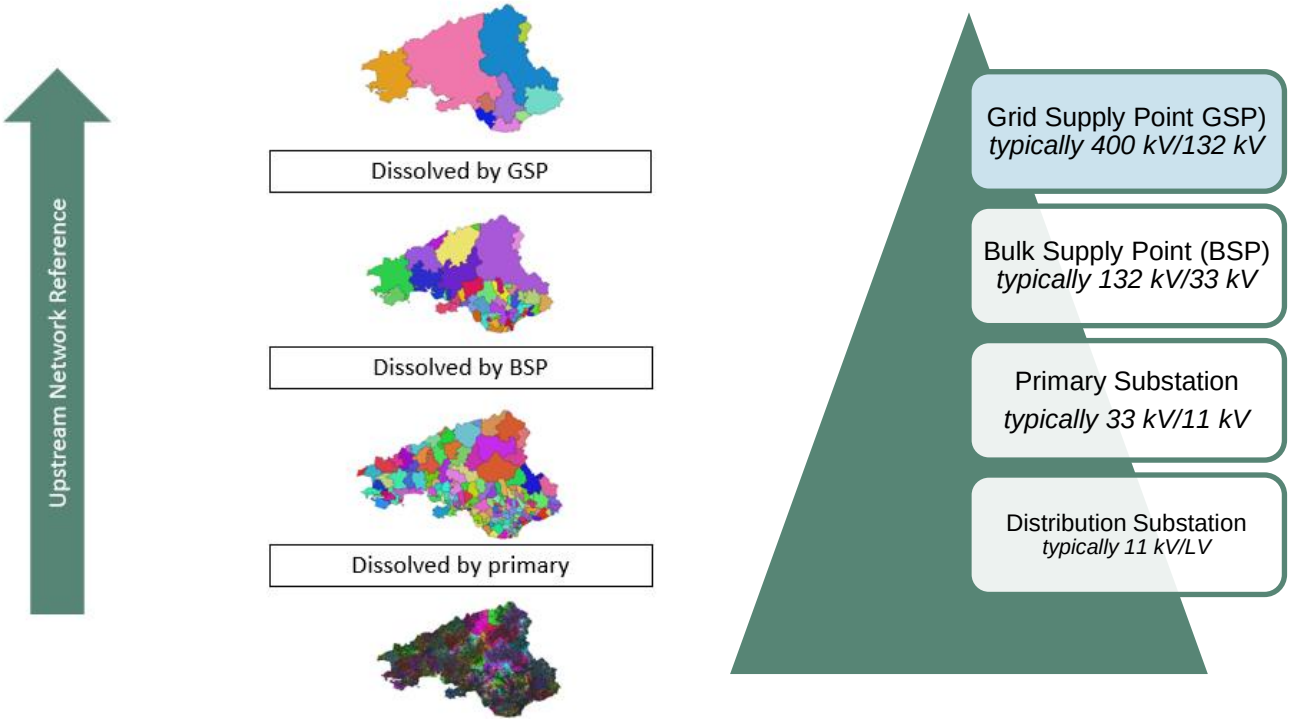

Figure 5 - South Wales distribution substation to GSP dissolving by network reference

What happens with single customers connected above LV?

The process outlined above does not account for customers which take supplies from the distribution network at a voltage above 11kV. As a result, these customer details are obtained through the WPD database of connected customers and each customer assigned a **Single Customer ESA**. This does not have an associated geographic area, as this will be captured in the geographic polygons for nearby distribution substations. Figure 6 shows how these single customers would not be captured in the ESA process. In many cases, it is beneficial to model the electrical behaviour of large single customers using a different methodology to a large group of LV connected customers. As a result, this process allows more detailed electrical analysis to take place.

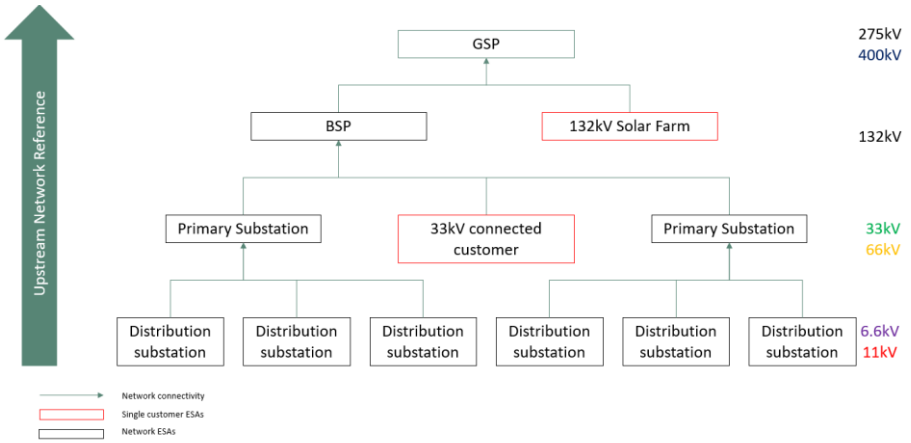

Figure 6 - Network Hierarchy

References

QGIS Development Team 2020. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org