

Executive Summary

This report corresponds to Deliverable 1.3 "Creation of non-validated computer-based models of monitored and generic LV networks ready to be used for planning studies" and Deliverable 1.4 "Report for WP 1-Task 1.2" both part of the Low Carbon Network Fund Tier 1 project "LV Network Solutions" run by Electricity North West Limited (ENWL).

The aim of the LV Network Solutions project is to provide ENWL with greater understanding of the characteristics, behaviour, and future needs of their low voltage networks. This will be based on the analysis of data gathered by appropriate monitoring schemes to be deployed on hundreds of LV feeders and substations, and the assessment of the corresponding computer-based network models in current and future scenarios.

In particular, this report explains the procedure to create the computer-based models for those ENWL LV networks that will be monitored throughout the project. Two networks have been fully modelled to date: Pavilion Way and Dunton Green. The former was initially given by ENWL so the corresponding translation tool can be developed (see report for Deliverable 1.2 "Tool for Translating Network Data from ENWL to OpenDSS"). The latter corresponds to Dunton Green that is also part of the project "Voltage Management on Low Voltage Busbars"). To show the readiness of the Dunton Green network model, initial studies were carried out. In particular, a comparison between the utilisation of average (or diversified) profiles (from Elexon data) and realistic residential profiles (from a computational model) was performed. Results are presented in this report.

The methodology to create the computer-based network models has been successfully tested. The University of Manchester is ready to apply it to the rest of the LV networks to be monitored in the project. However, in order to align our work to the original schedule it is crucial that ENWL provide all the necessary data in a timely manner.

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1 Introduction

As part of the transition towards a low carbon economy, Electricity North West Limited (ENWL), the Distribution Network Operator of the North West of England, is involved in different projects funded by the Low Carbon Network Fund. The University of Manchester is part of the Tier 1 project "LV Network Solutions".

The objective of this project is to provide ENWL with greater understanding of the characteristics, behaviour, and future needs of their LV networks. This will be based on the analysis of data gathered by appropriate monitoring schemes to be deployed on hundreds of LV feeders and substations, and the assessment of the corresponding computer-based network models in current and future scenarios.

1.1 Deliverables 1.3 and 1.4

The main objective of these deliverables is the creation of computer-based models of the monitored LV networks. These models will be crucial to assess the corresponding impacts of Distributed Energy Resources from the planning and operational perspectives.

At the moment, GIS-based information of six out of the (approximately) two hundred substations to be monitored has been received by the University. These six networks are also part of another ENWL project called "Voltage Management on Low Voltage Busbars" which has a shorter duration hence the need for processing them first. The networks received are: Dunton Green, Edge Green, Greenside, Howard St, Landgate and Leicester. Nevertheless, only two of them, Dunton Green and Howard St, have 'cleaner' sets of data that can be used to produce the corresponding computer-based models.

Previous to this report, GIS-data for the Pavilion Way network was given to the University (see report for Deliverable 1.2 "Tool for Translating Network Data from ENWL to OpenDSS"). Although this network is not going to be monitored, its computer-based model was produced.

In this report, the process to create the models is described. First of all, the GIS-based data is pre-processed. Then, the connectivity procedure (explained in detail in Delivery 1.2) is carried out. Finally, the fully connected network is translated into OpenDSS – the tool to be used for the impact studies. To demonstrate the capabilities of the computer representation a comparison between the utilisation of average (or diversified) profiles (from Elexon data) and realistic residential profiles (from a computational model) was carried out. This study takes into account the time-series nature of electricity consumption and compares the impact in voltages and currents for both approaches.

2 Information Received

The main aim of this part of the project is to be able to create a computer representation for approximately one thousand feeders associated with the two hundred monitored substations. At the moment, GIS network data for six of the substations has been received. These networks are:

1. Dunton Green;
2. Edge Green;
3. Greenside;
4. Howard St;
5. Landgate; and,
6. Leicester.

All of these networks were received in separated folders; each of them contains the GIS representation of the network. In particular, the GIS data has two main files with three different extensions for each of them (.SHP, .SHX, .DBF). The file called polyline contains the information about the network topology; this is the connection among the line segments and the main characteristics of those segments. The file with the information about the position of special devices is called "points", for example this file contains the beginning of the lines and the feature number of each feeder.

Using the files above mentioned it is possible to visualise all the information included in the folder received. In fact, Figure 1, Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 show the topology for Dunton Green, Edge Green, Greenside, Howard St, Landgate and Leicester, respectively.

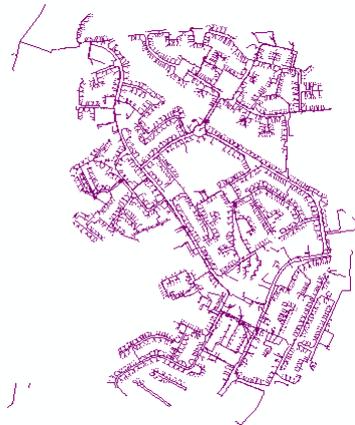


Figure 1: Visualisation of the information in Dunton Green folder



Figure 2: Visualisation of the information in Edge Green folder



Figure 3: Visualisation of the information in Greenside folder



Figure 4: Visualisation of the information in Howard Street folder



Figure 5: Visualisation of the information in Landgate folder

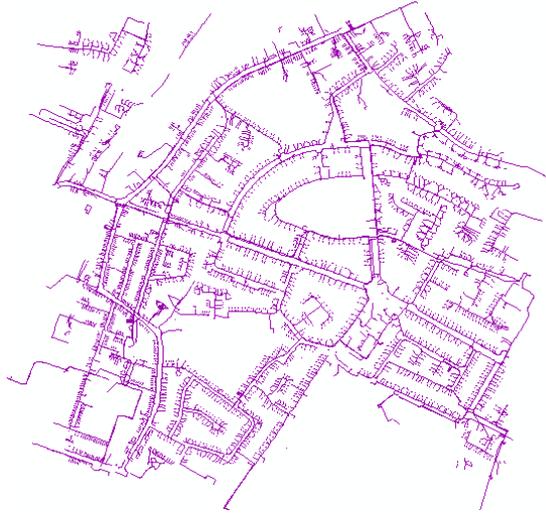


Figure 6: Visualisation of the information in Leicester folder

From the visual inspection of the previous figures associated with the GIS files received, it can be observed that each topology seems bigger than a normal LV network (i.e., set of feeders associated with a single substation). In fact, each folder with GIS information contains more than one network, which means it has the relevant network (e.g., Dunton Green) and some surrounding networks that are not part of the project. For example, Figure 7 shows all of the MV/LV substations (light blue circles) in the folder named Dunton Green. The number of substations in the same folder is 18 (see Table 1). Hence, it is necessary to recognise which of the 18 networks is the relevant network (in this case, Dunton Green).



Figure 7: MV/LV substations in Dunton Green folder

Unfortunately, from the data available it was not possible to recognise the relevant network. This is mainly because each substation has a particular reference number (ID Substation in Table 1) which is not related with a particular name in the information proportioned. In order to solve this problem, ENWL was requested to include just one network in each folder. In this way, the relationship between the network and the name of the folder is one to one.

	ID substation		ID substation
1	234000018	10	260063067
2	234056955	11	260066713
3	235029980	12	261006174
4	235030068	13	261011303
5	235030130	14	261011430
6	260053350	15	261011624
7	260053638	16	261011733
8	260055601	17	261039513
9	260057651	18	514957064

Table 1: Summary of Substation IDs in the Dunton Green folder

2.1 New information

Dunton Green and Howard Street were received in the new format required. For illustration, the left side of Figure 8 indicates the Dunton Green topology from the data initially received. In contrast, the right side of Figure 8 indicates the GIS information contained in the new Dunton Green folder, where it can be observed that only the Dunton Green topology (the relevant network) is considered.

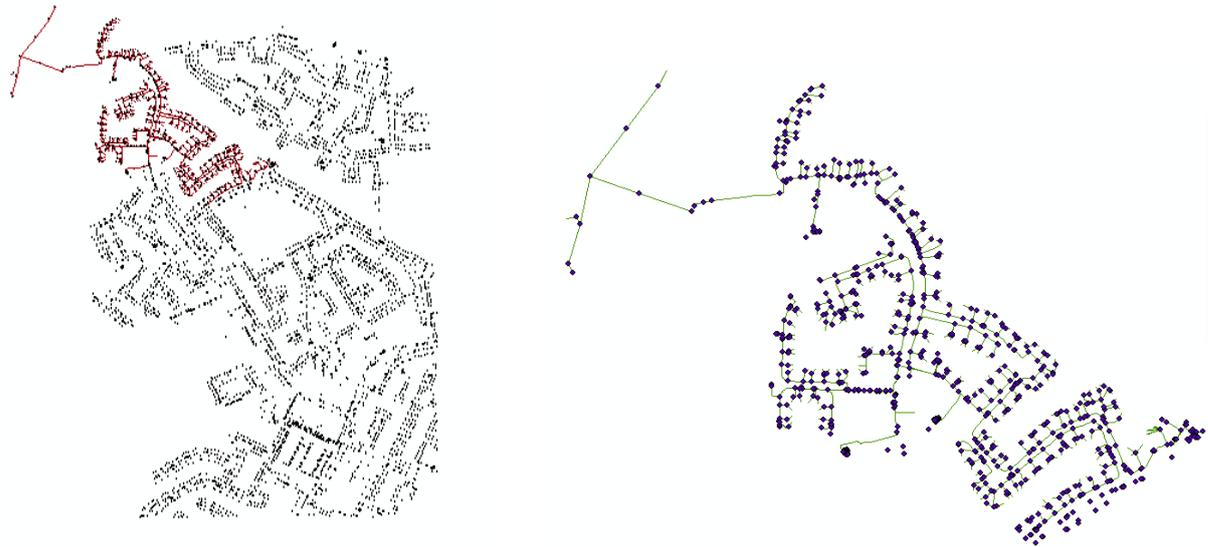


Figure 8: Dunton Green Identification

3 Creation of networks

Having the networks information in the proper format (one folder one network) it is possible to start the creation of the corresponding computer-based models. The main stages of this process are: feeder identification, creation of the line segments, topology reconnection and the representation in OpenDSS. Because some of these processes were explained in detail in previous reports (see Deliverable 1.2), this section will provide a brief summary about all of them. Dunton Green will be used as an example of the process.

3.1 Feeder identification

Proper identification of each feeder is crucial so computer-based models can be related to the monitored data. The validation of the models and further analyses to be carried out in this project depend on this step.

From the new information (i.e., one folder one network), it is possible to identify the feeder ID (given by the "Feature number") by cross checking information from the two main GIS files for each feeder: relating the shape file for the polyline and the shape file for the points in each feeder.

The polyline shape contains a specific code to identify each feeder (CSECTID), this code is used also in the points shape, which contains the feature number for each feeder. Therefore, it is possible to relate both files through the CSECTID code and get the feature number. However, one intermediate step is needed. The feature number is associated with the first segment of the feeder (Header) so after relating the two data bases with CSECTID, the result needs to be filtered so the first segment of the feeder can be identified. This is possible by using the WAY_NO (way number) since only the first segment has a value different to zero in this database field. The results of this process for Dunton Green are shown in Table 2.

WAY_NAME	WAY_NO	WAY_TYPE	S_YCOORD	S_XCOORD	FEATNO	FEATURE_0	STRING11	CSECTID
PE 38 PENSHURST RD 2W BX	5	G*	392887.38	390872.664	260055783	lv_fuseway	260055601	999138280
THE CLOUGH	4	G*	392887.866	390872.781	260055780	lv_fuseway	260053660	999138430
NORTHUMBERLAND ODD FS PE	3	G*	392888.352	390872.899	260055773	lv_fuseway	260055804	999132116
NORTHUMBERLAND EVEN NS PE	2	G*	392888.838	390873.016	260055770	lv_fuseway	234056955	999131983
TRANSFORMER	1	GS	392889.323	390873.134	260055767	lv_linkway	260055804	999138553

Table 2: Feeders Identification for Dunton Green Network

This process is also useful to identify the position (coordinates) of the first segment. This identification will be important for the network construction in the next stages. Figure 9 indicates the location associated with the feature number of each feeder (light blue dots). The figure on the right hand side is the zoom in of Dunton Green transformer substation.



Figure 9: Feeder Location in Dunton Green Network

3.2 Creation of the line segments

The GIS files use the concept of polyline to store the data. In simple words, the polyline is a continuous line comprised by one or more line segments which is treated as a single object within the GIS. Hence, there is no direct visualisation about the information (i.e., coordinates, type of cable, type of connection, etc.) of each single segment. Nonetheless, that information is crucial to create the computational representation of the networks in OpenDSS and any other distribution network analysis software package.

With the purpose of knowing the information of each single segment, a semi-automatic process needs to be done in ARCGIS 9.2. This process is applied to the file with the polyline information, specifically to the shape file (extension .SHP). The stages of this procedure are:

1. Split line at vertices: The polyline is divided into segments. Each of them contains the whole information of the polyline, which means if the polyline has a "feature A", each segments has the same "feature A".
2. Vertices to points: This function indicates the vertices of each segment previously determined.
3. Add XY coordinates: This function includes the coordinates of each vertex for each segment of the polyline.

The names of the previous stages correspond to the same names of the specific tool located in the Data Management Tool in the ArcToolBox in ARCGIS 9.2.

3.3 Topology reconnection

To develop planning or operational studies that require power flow simulations, it is fundamental that every line segment in the network is connected. Unfortunately, as it was described in the Deliverable 1.2, the topologies in the ENWL GIS files are not totally connected. Indeed, there are many feeders or segments that seem connected but in reality they are separated by very small distance (from millimetres to a couple of centimetres). Consequently, the next steps to reach the computational representation are: identification of the connectivity problems and solution of these problems.

The easy way to identify the connectivity issues is through the determination of the connected components. A connected component of a graph is a sub-graph in which any vertices are connected to each other by paths (by definition one connected component is not connected to another connected component).

The methodology implemented to calculate the connected components was the Breath First Search Algorithm. As an example, the connected components for each feeder of Dunton Green are presented in Table 3.

Feeder (Way_NO)	Number of connected components	CI
2	19	36%
3	8	89%
4	3	98%
5	9	90%

Table 3: Connected components for Dunton Green Network

From Table 3 it is possible to observe that the number of connected components is bigger than one, which means that there are connectivity problems in the network under analysis. However, the number of problems is different among the feeders. The third column in Table 3 indicates the connectivity index (CI) which is the proportion between the main feeder (defined as the longer connected component in one feeder) and the total feeder length. Thus, if the CI is 100% it means that the feeder is totally connected.

Figure 10 shows the connected components visualisation (from way number 2 to way number 5), where different colours represent different connected components and the main connected component is depicted with the black line.

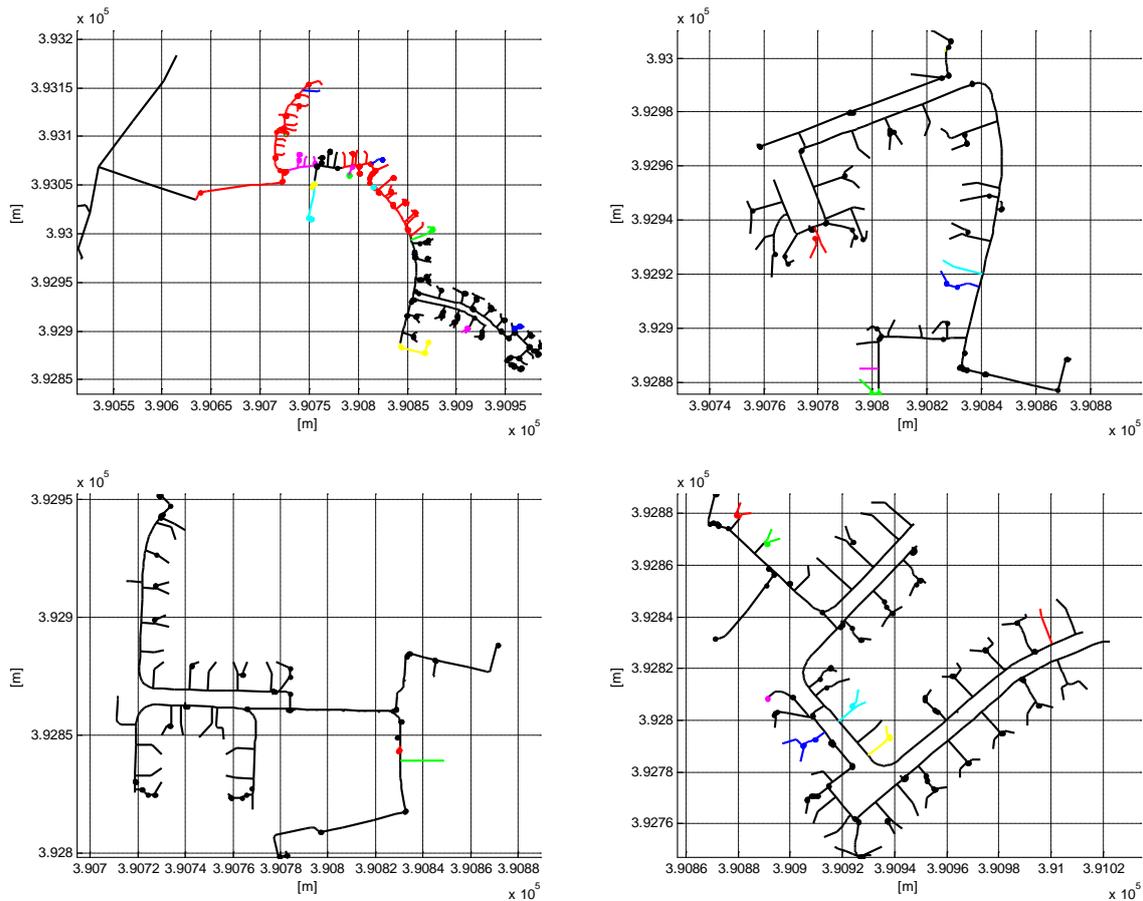


Figure 10: Connected Components of Dunton Green Network

Once the connected components are identified, the next step is the reconnection process. Basically, this step joins every single connected component to the main one in order to have a totally connected feeder. The flow chart of this process is presented in Figure 11 (for further information see Deliverable 1.2).

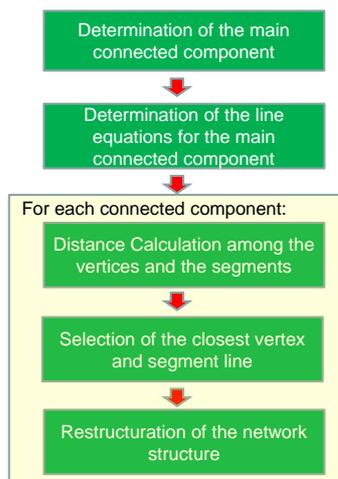


Figure 11: Flow chart of the reconnection process

The application of the reconnection process for Dunton Green feeders are shown in Figure 11, getting a connectivity index for every feeder equal to 100%. Thus, the Dunton Green network is totally connected.

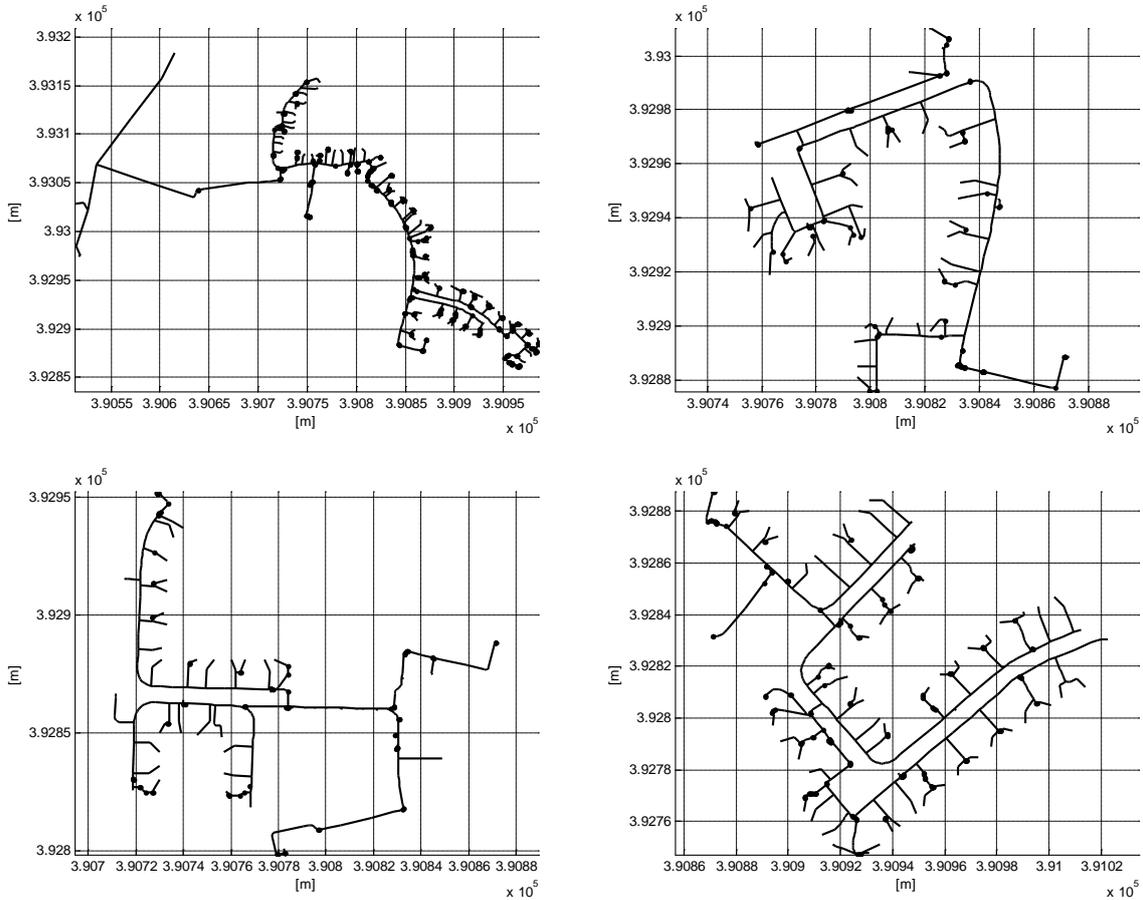


Figure 12: Reconnection process in Dunton Green

The last stage to create the computer-based models, i.e., the representation in OpenDSS, is explained in the next section.

4 OpenDSS Representation

OpenDSS is an open source software package to solve power flows, harmonics analysis and fault current calculations in electrical distribution systems. This computational tool was developed by the EPRI (USA) to initially help with the analyses associated with distributed generation. Indeed, it can represent the time dimension (daily and yearly simulations with different time step), which is very important to measure the real impacts of variable sources (PV systems, micro-CHP, micro-wind turbines, etc.) and loads (EVs, EHPs, etc.) on distribution networks.

In order to use this software, the information received (GIS files) needs to be translated into OpenDSS format. The flow chart of the translation process is shown in Figure 13.

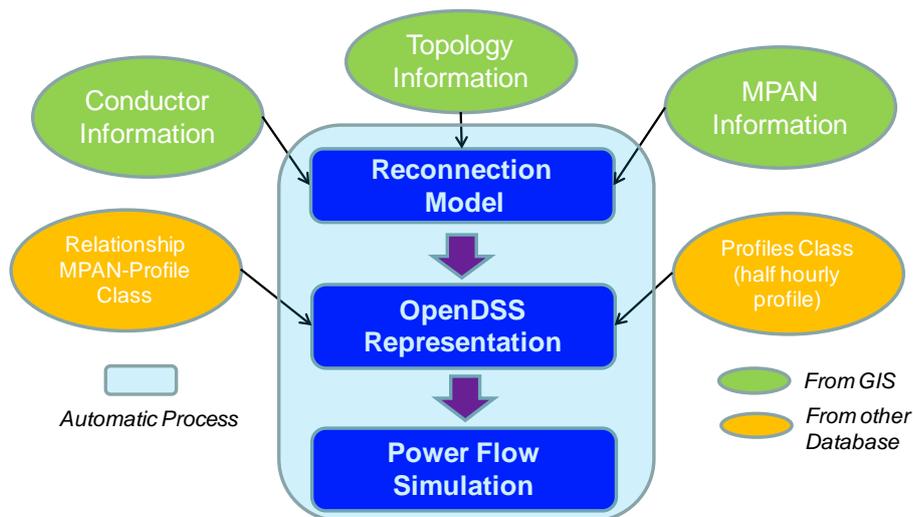


Figure 13: Automatic Translation to OpenDSS

The conductor, topology and MPAN (Meter Point Administration Number) information comes from the GIS files. The half hourly profiles come from the Elexon data (this information will be replaced for models created from the data collected during the monitoring campaign). Finally, the database to relate the MPANs with the profiles classes is provided by ENWL. However, this information for the monitored substations has not been received yet.

Using the information received it is possible to create a structured set of files that allow the LV networks to be represented in OpenDSS format. The files automatically created are:

Lines.txt: After the application of the reconnection methodology, the precise connection between vertices is known. Also known, from the database, is the type of cable and the distance between two. With this information the line file is created in MATLAB and the result is saved as a TXT file (OpenDSS can read files from this format).

Loads.txt: This file indicates to which bus the loads are connected, the type of load (single-phase or three-phase), the nominal voltage and the power factor. Additionally, this file incorporates an important part to execute time-series analyses: the load shape (load profile) associated with each load. Here, only the load shape names are incorporated, their characteristics are indicated in a different file.

LoadShapes.txt: This file provides the electrical behaviour of one load along a given period. This file includes the path where the profile (shape) is located. Each profile is located in one TXT file.

LineCode.txt: This file incorporates the network parameters. The name of these conductors is the same name used in the Lines.txt file.

Transformers.txt: This file has the technical parameters of transformers.

Monitors.txt: This file indicates the position where the monitors are located. The technical information from the network (i.e., voltages, currents, active power, etc.) can be obtained just in the locations with

monitors. Therefore, the automatic process allocates monitors at least in each customer to check the voltage profiles and in the main lines to check thermal limits.

For illustration, Figure 14, Figure 15 and Figure 16 show one snapshot of the line, load shape and line code files, respectively, in OpenDSS format. Snapshots of all the files are shown in the Appendix.

```

File Edit Format View Help
New Line.LINE1 Bus1=1 Bus2=2 Linecode=185mm2 Length=1.1254 Units=m
New Line.LINE2 Bus1=2 Bus2=3 Linecode=185mm2 Length=5.4882 Units=m
New Line.LINE3 Bus1=3 Bus2=4 Linecode=185mm2 Length=0.13601 Units=m
New Line.LINE4 Bus1=4 Bus2=5 Linecode=185mm2 Length=0.1253 Units=m
New Line.LINE5 Bus1=5 Bus2=6 Linecode=185mm2 Length=0.59034 Units=m
New Line.LINE6 Bus1=6 Bus2=7 Linecode=185mm2 Length=0.1118 Units=m
New Line.LINE7 Bus1=7 Bus2=8 Linecode=185mm2 Length=0.21039 Units=m
New Line.LINE8 Bus1=8 Bus2=9 Linecode=185mm2 Length=0.11963 Units=m
New Line.LINE9 Bus1=9 Bus2=10 Linecode=185mm2 Length=0.13153 Units=m
New Line.LINE10 Bus1=10 Bus2=11 Linecode=185mm2 Length=0.24088 Units=m
New Line.LINE11 Bus1=11 Bus2=12 Linecode=185mm2 Length=0.22837 Units=m
New Line.LINE12 Bus1=11 Bus2=13 Linecode=185mm2 Length=0.23087 Units=m
New Line.LINE13 Bus1=11 Bus2=14 Linecode=185mm2 Length=1.8753 Units=m
New Line.LINE14 Bus1=12 Bus2=15 Linecode=185mm2 Length=0.21024 Units=m
New Line.LINE15 Bus1=13 Bus2=16 Linecode=185mm2 Length=0.89441 Units=m
New Line.LINE16 Bus1=14 Bus2=17 Linecode=185mm2 Length=14.5512 Units=m
New Line.LINE17 Bus1=14 Bus2=18 Linecode=185mm2 Length=5.6338 Units=m
New Line.LINE18 Bus1=15 Bus2=19 Linecode=185mm2 Length=0.27203 Units=m
New Line.LINE19 Bus1=16 Bus2=20 Linecode=185mm2 Length=14.814 Units=m
New Line.LINE20 Bus1=16 Bus2=21 Linecode=185mm2 Length=5.1545 Units=m
New Line.LINE21 Bus1=18 Bus2=22 Linecode=185mm2 Length=2.1869 Units=m
New Line.LINE22 Bus1=19 Bus2=23 Linecode=185mm2 Length=0.33541 Units=m
New Line.LINE23 Bus1=21 Bus2=24 Linecode=185mm2 Length=13.2567 Units=m
New Line.LINE24 Bus1=21 Bus2=25 Linecode=185mm2 Length=2.9151 Units=m
New Line.LINE25 Bus1=22 Bus2=26 Linecode=185mm2 Length=2.2895 Units=m
New Line.LINE26 Bus1=23 Bus2=27 Linecode=185mm2 Length=0.36401 Units=m
New Line.LINE27 Bus1=25 Bus2=28 Linecode=185mm2 Length=1.672 Units=m
New Line.LINE28 Bus1=26 Bus2=29 Linecode=185mm2 Length=0.76601 Units=m
New Line.LINE29 Bus1=26 Bus2=30 Linecode=185mm2 Length=2.0834 Units=m
New Line.LINE30 Bus1=27 Bus2=31 Linecode=185mm2 Length=0.65605 Units=m
    
```

Figure 14: Example of line file

```

File Edit Format View Help
New Loadshape.Shape_1 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_2 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_3 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_4 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_5 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_6 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_7 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_8 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_9 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Load
New Loadshape.Shape_10 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_11 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_12 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_13 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_14 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_15 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_16 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_17 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_18 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_19 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_20 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
New Loadshape.Shape_21 npts=48 interval=0.5 mult=(file-d:\2012\Models\ENWL\Connectivity_to_OpenDSS\Connectivity\Load_files_ENWL\Loa
    
```

Figure 15: Example of load shape file

```

File Edit Format View Help
New Linecode.95mm2 R1=0.32 R1=0.32 X1=0.069 R0=0.96 X0=0.207 C1=0 C0=0 Units=km
New Linecode.185mm2 R1=0.164 R1=0.164 X1=0.0685 R0=0.492 X0=0.2055 C1=0 C0=0 Units=
New Linecode.300mm2 R1=0.1 R1=0.1 X1=0.0675 R0=0.3 X0=0.2025 C1=0 C0=0 Units=km
New Linecode.2x185mm2 R1=0.082 R1=0.082 X1=0.0343 R0=0.246 X0=0.1029 C1=0 C0=0 Unit
New Linecode.2x300mm2 R1=0.05 R1=0.05 X1=0.0338 R0=0.15 X0=0.1014 C1=0 C0=0 Units=ki
New Linecode.3x300mm2 R1=0.0333 R1=0.0333 X1=0.0225 R0=0.0999 X0=0.0675 C1=0 C0=0 U
New Linecode.25mm2_OH R1=0.32 R1=0.32 X1=0.069 R0=0.96 X0=0.207 C1=0 C0=0 Units=km
New Linecode.95mm2_OH R1=0.32 R1=0.32 X1=0.29 R0=0.96 X0=0.87 C1=0 C0=0 Units=km
New Linecode.185mm2_OH R1=0.164 R1=0.164 X1=0.28 R0=0.492 X0=0.84 C1=0 C0=0 Units=ki
New Linecode.300mm2_OH R1=0.1 R1=0.1 X1=0.276 R0=0.3 X0=0.828 C1=0 C0=0 Units=km
New Linecode.2x185mm2_OH R1=0.082 R1=0.082 X1=0.14 R0=0.246 X0=0.42 C1=0 C0=0 Units
New Linecode.2x300mm2_OH R1=0.05 R1=0.05 X1=0.138 R0=0.15 X0=0.414 C1=0 C0=0 Units=
New Linecode.3x300mm2_OH R1=0.0333333333333333 R1=0.0333333333333333 X1=0.092 R0=0.
    
```

Figure 16: Example of line code file

The automatic process presented above can be applied to any ENWL GIS file.

4.1 Computer-Based Model

To analyse the capabilities of the computer models for the monitored networks, this section will study the impacts of different load profile data on the Dunton Green network.

4.1.1 Network Data and Assumptions

The network data comes from the GIS information after being re-connected and translated into OpenDSS. The network used as an example is Dunton Green; it has four feeders (way numbers 2, 3, 4 and 5), about 3000 line segments, a total length of 5.36 km and 180 customers connected. The large amount of segments is because of the process "split line at vertices", where the polyline is separated in segments in order to represent in detail the network and therefore be able to run power flow simulations. The characteristic for each particular feeder are presented in Table 4.

Way_NO	Number of Segments	Length [m]	Number of MPANs
2	1141	2290	70
3	483	868	31
4	499	920	26
5	865	1287	53
Total	2988	5365	180

Table 4: Main characteristics of Dunton Green Network

Figure 17 indicates the Dunton Green Network after the reconnection process, each colour represents one feeder and the triangle indicates the transformer location.

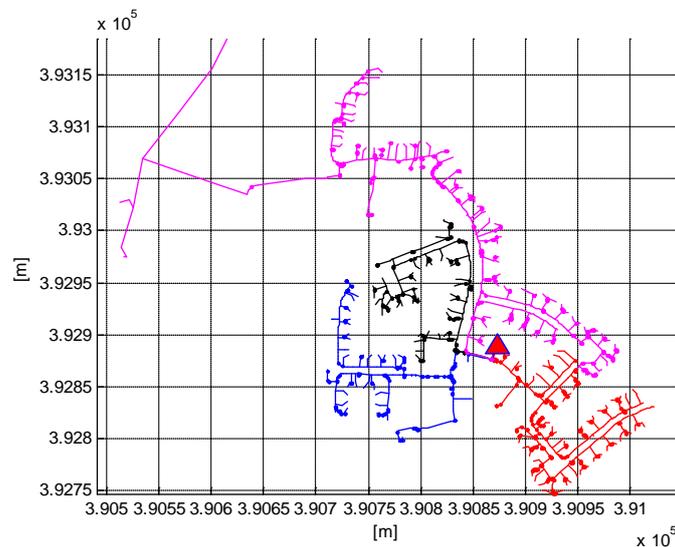


Figure 17: Dunton Green Network

Due to the big amount of information associated with LV networks and the impossibility to have a perfect GIS management system for LV networks, some information is missing in the files received. With the purpose of completing that information the following assumptions were considered:

1. **Phase connection.** The available information about the phase connection in the data base is mostly indicated by R (red), Y (yellow) and B (blue) for the single phase cables and RYB for the three phase cables. However, there are some cases where the codes are different:
 - a. Some phase connections are indicated with 1P, we assume that means single phase. The loads with 1P identifier are randomly allocated to one phase (R, Y or B); each phase has the same probability to be selected.
 - b. Some phase connections are indicated with W. In the feeder with this problem, the rest of the phases are indicated with R and B, so our assumption is that W means Y phase.
2. **Cable type.** For the cables with information about the phase connection but without information about the type of cable, the conductor information is filled by using the most common service cable in the feeder to supply single phase loads.

3. **MPAN connection.** The customers connected (MPAN connection) through a line without conductor information will take the information from the conductor immediately upstream. If the line upstream does not have information, the process follows with the next line upstream. Additionally, if the line upstream has three phases then the MPAN, which is single phase, will take the most common cable for single phase connection.
4. **Three-phase cables.** For the three phase cables without conductor information, the line will take always the information from the conductor immediately upstream. If the line upstream does not have one, the process follows with the next line upstream.
5. **Impedance.** To allocate the impedance values for each conductor, the ENWL practice code is used. However, it is not always possible to identify which conductor in the database corresponds to which conductor in the practice code. As an interim solution, if the size of the cable and the phase connection are available but it is not possible to identify the conductor code, then the most common cable for the same size and connection is chosen.

4.1.2 Residential Load Model

In order to run power flow simulations, it is crucial to know the behaviour of the load. One source of load profiles to run power flow simulations is the computational model developed for CREST (Centre for Renewable Energy Systems Technology) at Loughborough University. This model creates computational profiles for residential loads based on the domestic behaviour of British costumers¹; it takes into account the number of people at home, the type of day, the month, and the use of the appliances. In this way, it is possible to have one minute resolution profiles, indicating which appliance is on and how much power it is using. The profiles are randomly created based on a pre-defined set of characteristics.

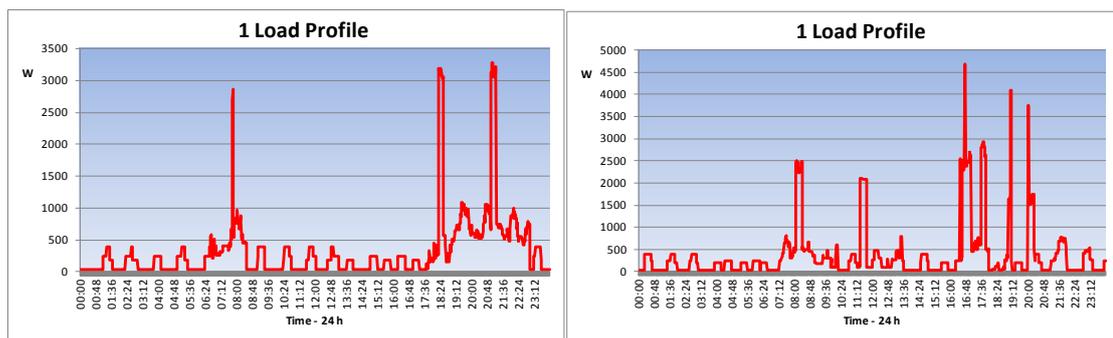


Figure 18: Residential load profiles

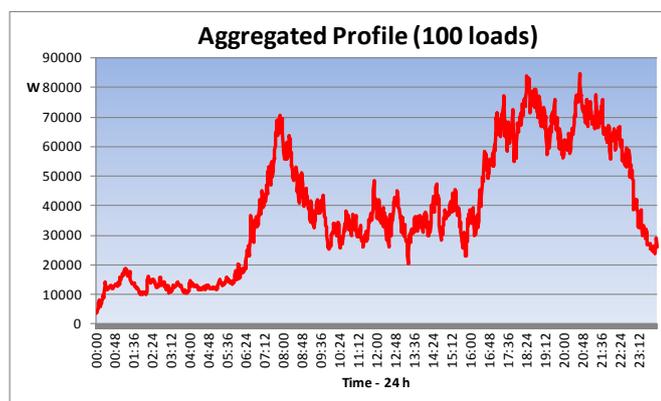


Figure 19: Aggregation of random load profiles

¹ I. Richardson, M. Thomson, D. Infield, and C. Clifford, "Domestic electricity use: A high-resolution energy demand model," Energy and Buildings, Vol. 42, No 10, pp. 1878-1887, 2010.

Here, the number of people at home was randomly allocated between 1 and 5. The available appliances are also randomly allocated. Figure 18 shows two residential profiles for a single house considering a typical weekday. The aggregation of one hundred of these random profiles behaves as expected for a collection of residential loads, as shown in Figure 19. It can be seen the morning peak around 8 AM and the peak demand period between 6 PM and 10 PM.

4.1.3 Elexon Profiles

Another source of information about the load profiles is Elexon. Indeed, it provides half-hourly aggregated profiles for eight different types of ENWL customers:

- Profile Class 1: Domestic Unrestricted Customers.
- Profile Class 2: Domestic Economy 7 Customers.
- Profile Class 3: Non-Domestic Unrestricted Customers.
- Profile Class 4: Non-Domestic Economy 7 Customers.
- Profile Class 5: Non-Domestic Maximum Demand (MD) Customers with a Peak Load Factor (LF) of less than 20%.
- Profile Class 6: Non-Domestic Maximum Demand Customers with a Peak Load Factor between 20% and 30%.
- Profile Class 7: Non-Domestic Maximum Demand Customers with a Peak Load Factor between 30% and 40%.
- Profile Class 8: Non-Domestic Maximum Demand Customers with a Peak Load Factor over 40%.

Although the relationship between the MPANs and the profile classes for Dunton Green is known, all customers will be assumed to be residential unrestricted in this analysis. As an example, Figure 20 shows the averaged (i.e., per customer) Elexon curve for the profile class 1 (November 1, 2010).

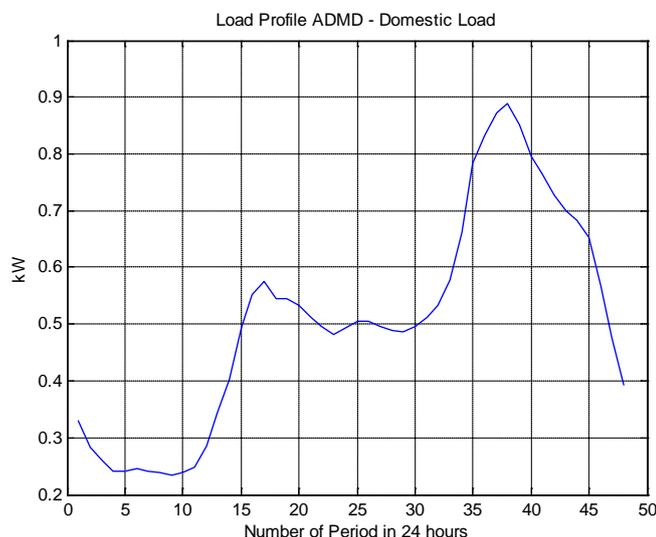


Figure 20: Average domestic profiles, PC 1

4.1.4 Impacts Analysis

The impacts of both approaches to represents load behaviour will be analysed. This analysis tries to show the capabilities of the computer-based model for Dunton Green. The study will be mostly focused on impacts on voltage given that the information about the thermal limits of the LV conductors is not available in the ENWL Code of Practice.

4.1.4.1 Using the load model

This analysis is done feeder by feeder. For each of them a number of random profiles are created and allocated to each MPAN. In particular, the granularity used is five minutes, so the number of periods during a single day is 288. Then, a power flow simulation is through OpenDSS using the computer-based model for Dunton Green. The results are presented below for each feeder considering a line-to-line voltage of 412V at the secondary of the distribution transformer.

4.1.4.1.1 Feeder Way 5

The feeder topology and the transformer location (green triangle) are shown in Figure 21.

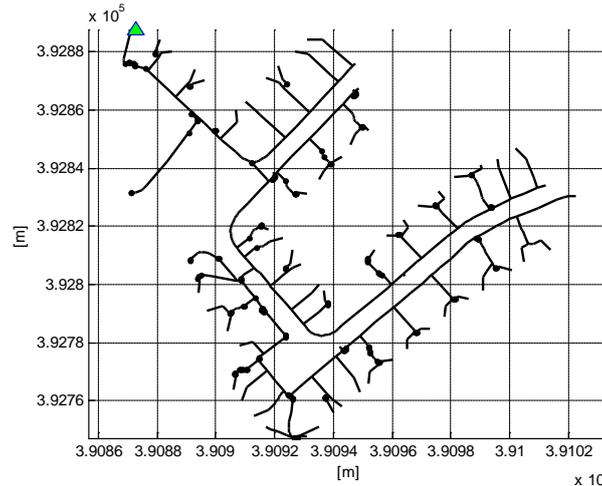


Figure 21: Dunton Green – Way 5

The load aggregated in this feeder is shown in Figure 22, the peak demand is 64.5 kVA and the minimum demand during the night time period is around 10 kVA. The number of customers in this feeder is 53, so the ADMD is approximately 1.21 kVA. It is important to observe that the ADMD is smaller than the real peak demand observed in the most remote load, which is above 3.5 kVA.

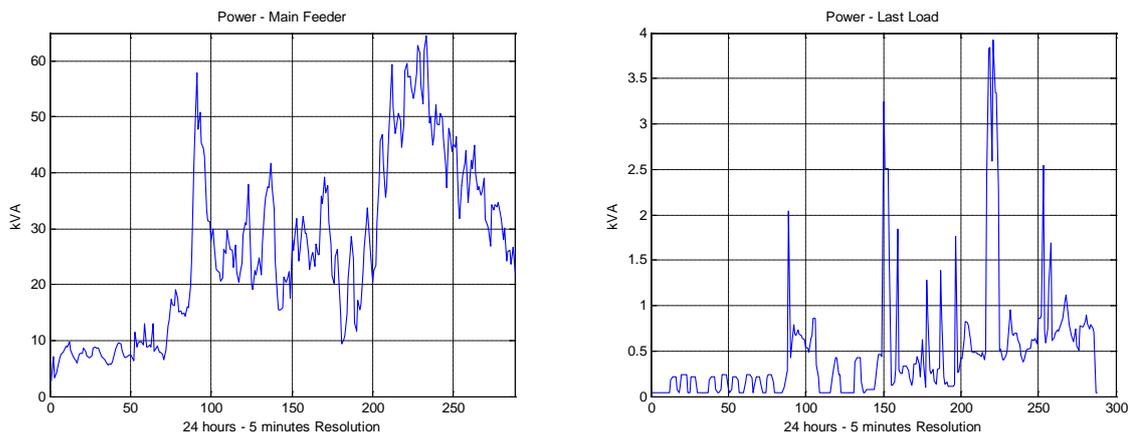


Figure 22: Load Profile at header feeder (left) and most remote load (right)

The voltage profiles for each load in the feeder are shown in Figure 23. The loads are sorted from the transformer to the most remote load. It is possible to observe the main voltage drop during the morning peak and during the afternoon peak.

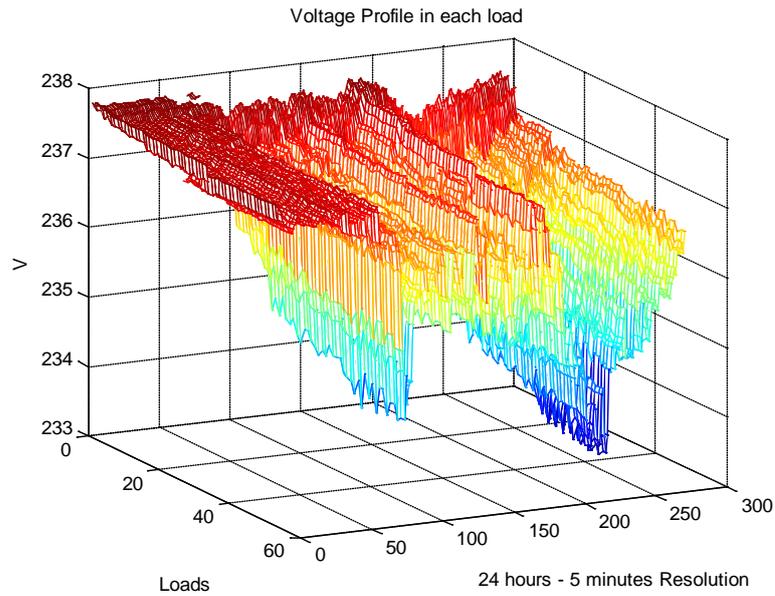


Figure 23: Voltage Profiles – Way 5

4.1.4.1.2 Feeder Way 4

The feeder topology and the transformer location (green triangle) for the way 4 are shown in Figure 24. The load aggregated in this feeder is shown in Figure 25, the peak demand is 30.5 kVA and the minimum demand during the night time period is around 5 kVA. The number of customers in this feeder is 26, so the ADMD is approximately 1.17 kVA. The peak demand observed in the most remote load is 2.8 kVA.

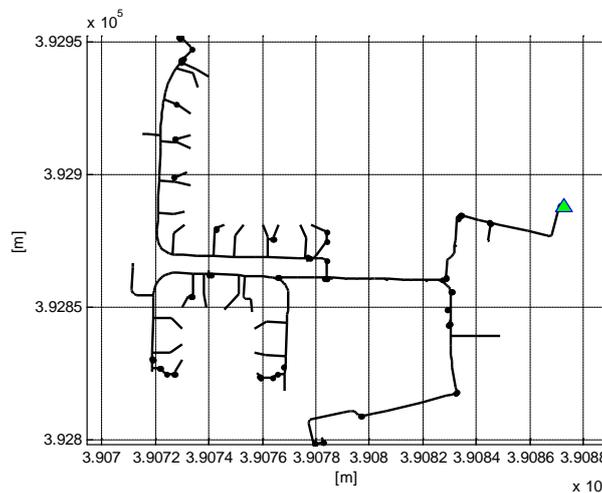


Figure 24: Dunton Green – Way 4

The voltage profiles for each load in the feeder are indicated in Figure 26. The loads are sorted from the transformer to the most remote load. The total voltage drop along the feeder is not that significant because of the small number of costumers connected to it.

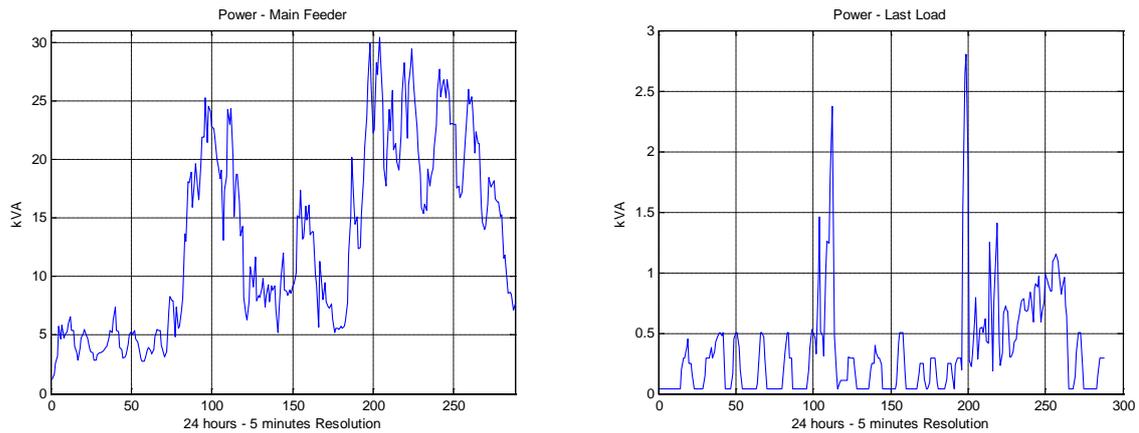


Figure 25: Load Profile at header feeder (left) and most remote load (right)

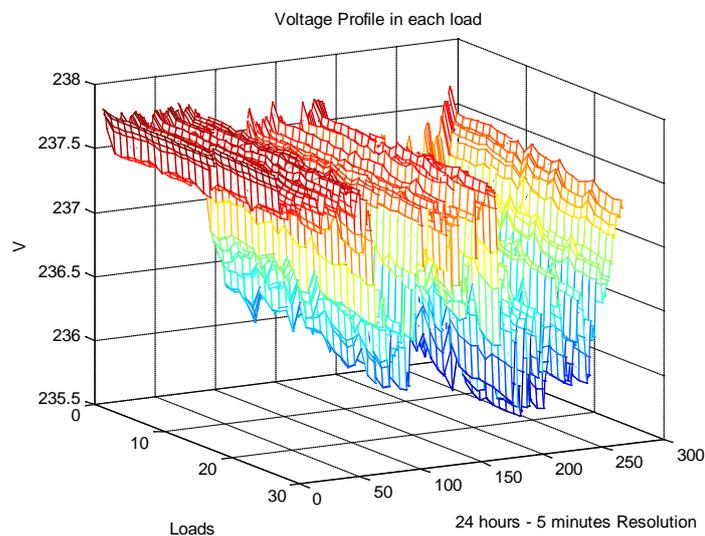


Figure 26: Voltage Profiles – Way 4

4.1.4.1.3 Feeder Way 3

The feeder topology and the transformer location (green triangle) are shown in Figure 27 for the way number 3.

The load aggregated in this feeder is shown in Figure 28, the peak demand is 40 kVA and the minimum demand during the night time period is around 5 kVA. The number of customers in this feeder is 31, so the ADMD is approximately 1.29 kVA. It is important to observe that the ADMD is smaller than the peak demand observed in the most remote load, which is about 3.5 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 29. The loads are sorted from the transformer to the most remote load. The total voltage drop along the feeder is not significant because of the small number of customers connected to it. In this feeder, the main voltage drop is during the peak demand period.

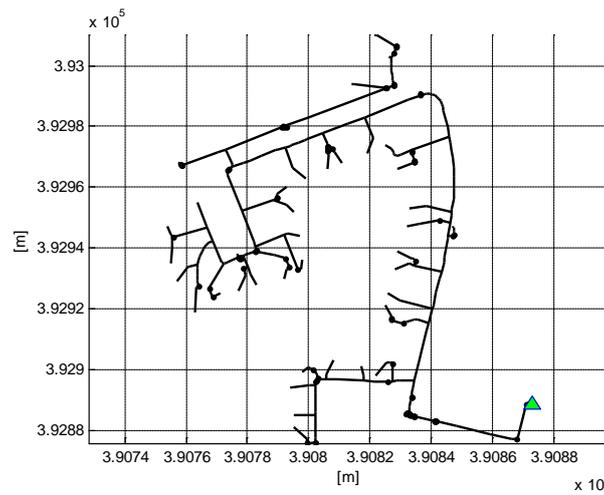


Figure 27: Duntun Green – Way 3

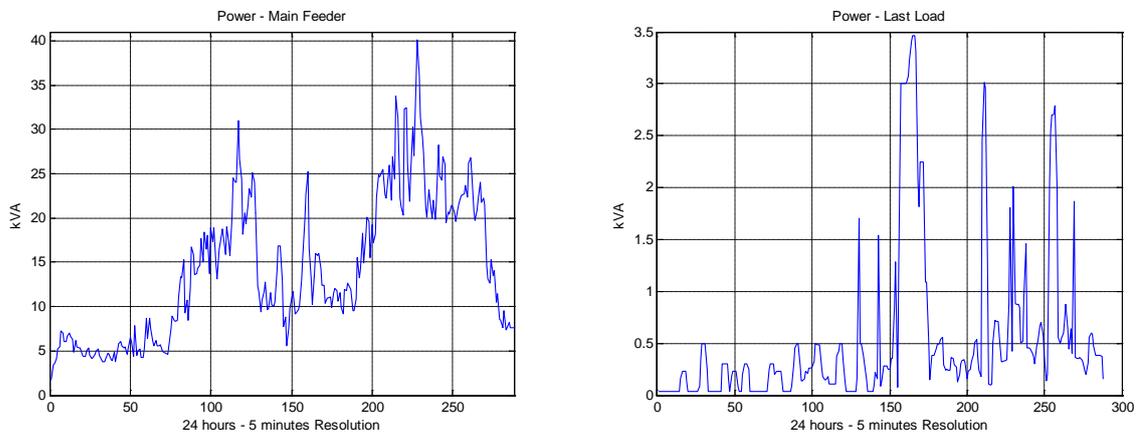


Figure 28: Load Profile at header feeder (left) and most remote load (right)

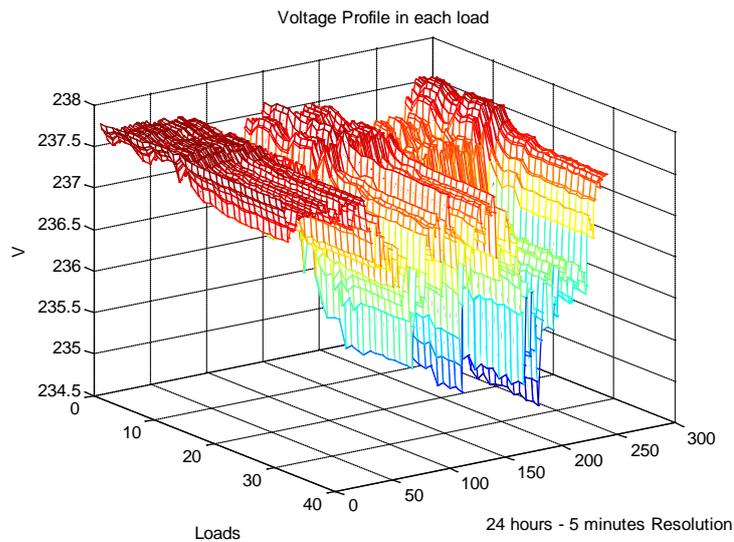


Figure 29: Voltage Profiles – Way 3

4.1.4.1.4 Feeder Way 2

The feeder topology and the transformer location (green triangle) are shown in Figure 30. This is the longest and loaded feeder of Dunton Green (2.2 km and 70 customers).

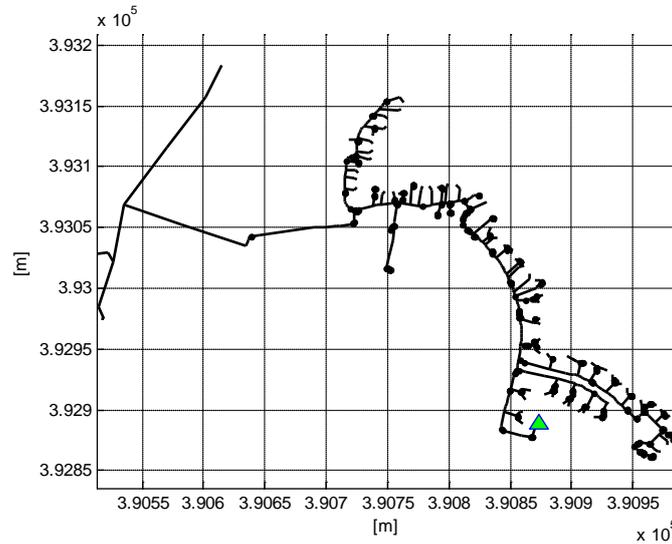


Figure 30: Dunton Green – Way 5

The load aggregated in this feeder is shown in Figure 31, the peak demand is 80 kVA and the minimum demand during the night time period is around 10 kVA. The number of customers in this feeder is 70, so the ADMD is approximately 1.14 kVA. In contrast, the peak demand observed in the most remote load is above 4 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 32. The loads are sorted from the transformer to the most remote load. Due to the length of this feeder (over 2 km) the voltage drop across the feeder is significant. To appreciate this effect in a better way, Figure 33 shows the comparison between the voltage profile at the header and the voltage profile at the most remote load.

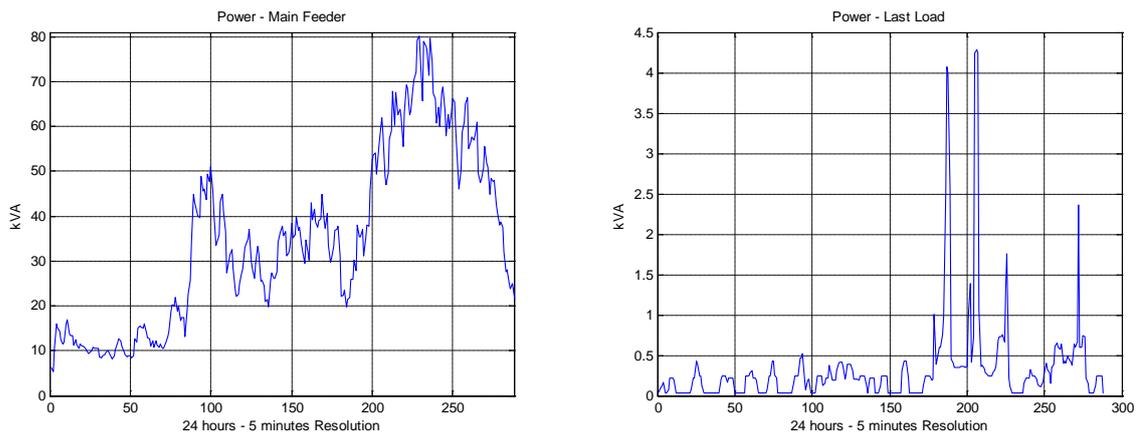


Figure 31: Load Profile at header feeder (left) and most remote load (right)

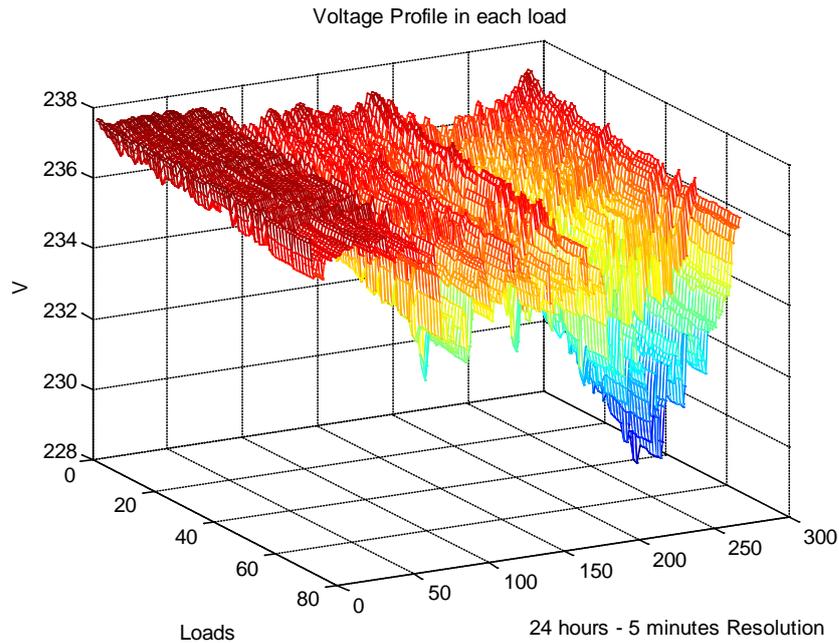


Figure 32: Voltage Profiles – Way 2

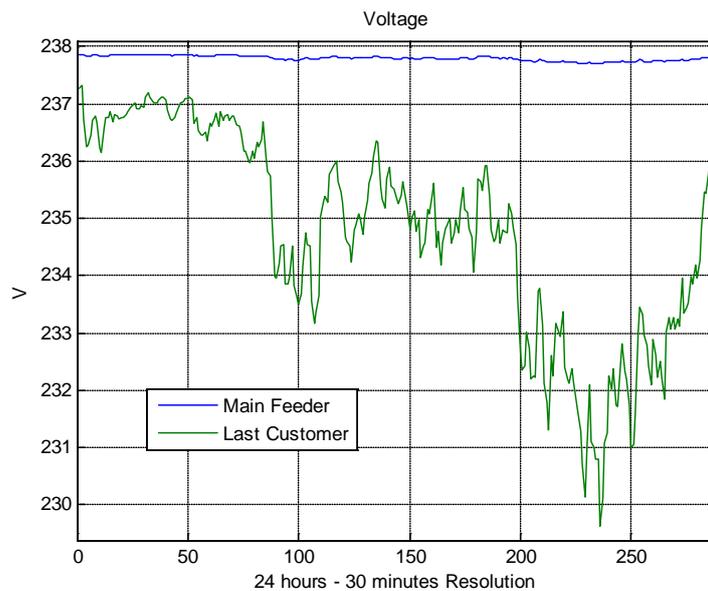


Figure 33: Voltage Profiles Comparison – Way 2

4.1.4.2 Using the Elexon profiles

This analysis is done feeder by feeder. All of the customers are assumed to be residential unrestricted (profile class one - Figure 20). A power flow simulation is run through OpenDSS using the computer-based model for Dunton Green. Due to the resolution profiles, these simulations are done with 30 minutes of granularity and therefore the day is divided into 48 periods. The results are presented below for each feeder.

4.1.4.2.1 Feeder Way 5

The aggregated profile for this feeder is indicated in Figure 34. Its peak demand is 47.5 kVA. This profile is simply the aggregation of the same profile (unrestricted profile) for every customer in the

feeder (all the costumers behave in the same way during the day). For that reason, it has exactly the same shape than the domestic unrestricted profile.

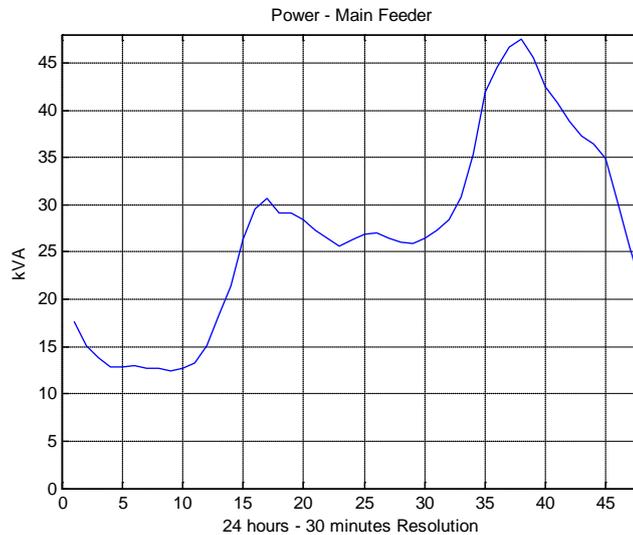


Figure 34: Aggregated Profile – Way 5

In order to have a better comparison between this approach and the 5 minutes resolution model, the unrestricted profile is scale in order to have the same peak demand in both cases. For example, in the case of the 5 minutes resolution model, the peak demand for way 5 was 64.5 kVA. Hence, the individual residential profile from Elexon is multiplied by $64.5/47.5$ (peak demand for 5 minutes resolution model/peak demand for Elexon data); the final profile is shown in Figure 35.

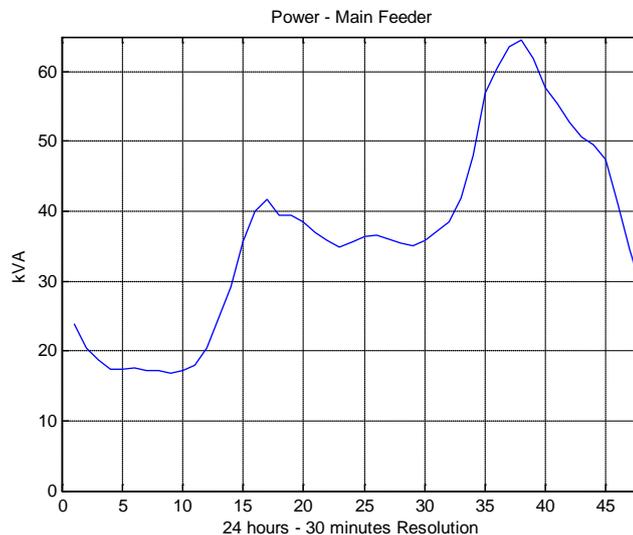


Figure 35: Aggregated Profile after the escalation – Way 5

Using this approach, the ADMD of 1.21 kVA is equal to the peak demand for each customer connected to this feeder; this means that there is not any load in the feeder with consumption bigger than 1.21 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 36. The loads are sorted from the transformer to the most remote load. In this case, there is not significant voltage drop during the morning time. All of the voltage profiles have similar shape, but the voltage drop is deeper for the loads further from the transformer.

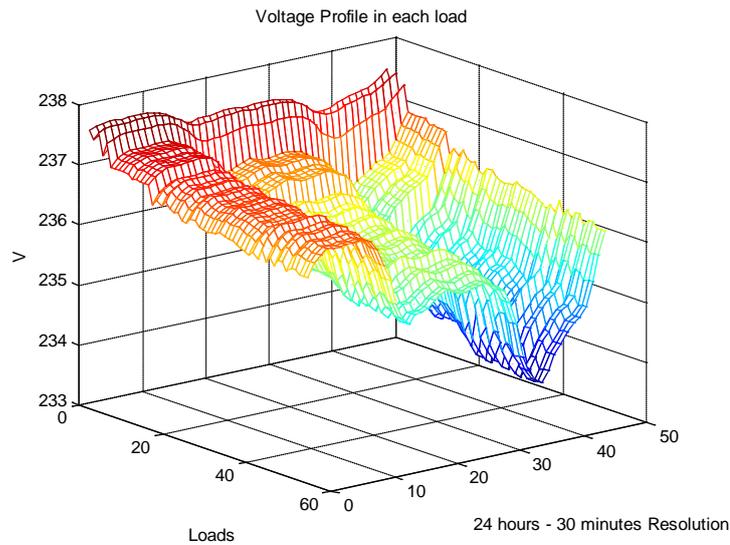


Figure 36: Voltage Profiles – Way 5

4.1.4.2.2 Feeder Way 4

The escalation process is also carried out in this case. The peak demand for 5 minutes resolution was 30.5 kVA and the aggregated demand from Elexon profiles is 23.2 kVA, therefore the factor is 1.31 (30.5 kVA / 23.2 kVA). The profile after the escalation process is in Figure 37.

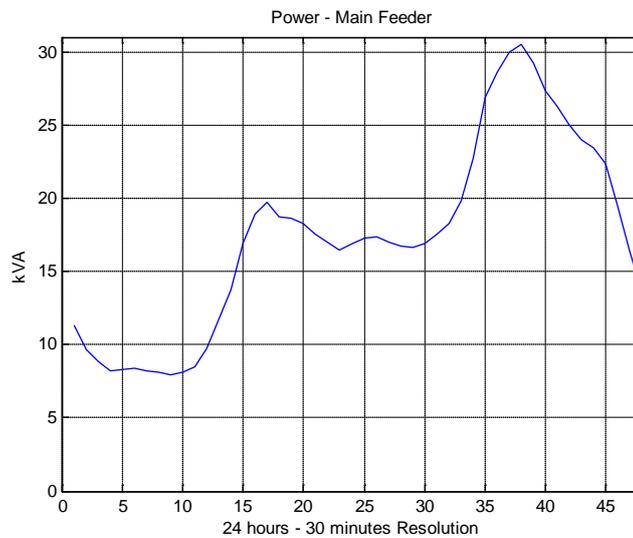


Figure 37: Aggregated Profile after the escalation – Way 4

Using this approach, the ADMD 1.17 kVA is equal to the peak demand for each customer connected to this feeder; this means that there is not any load in the feeder with consumption bigger than 1.17 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 38. The loads are sorted from the transformer to the most remote load. All of the voltage profiles have similar shape, but the voltage drop is deeper for the loads further from the transformer.

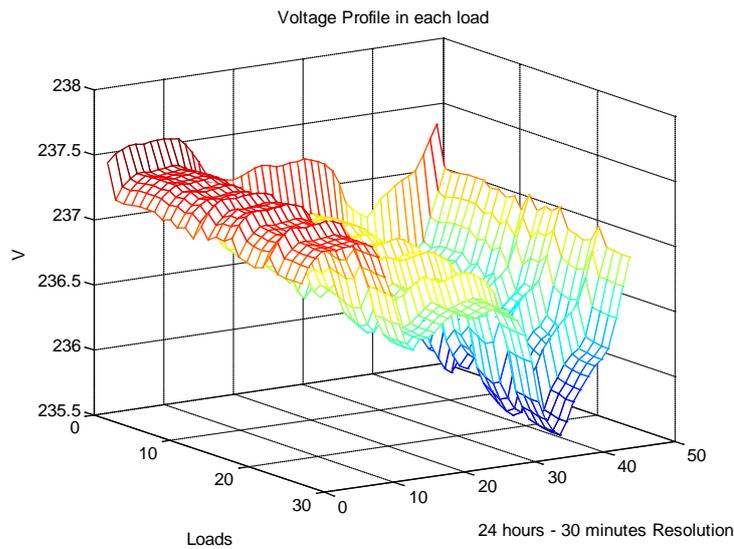


Figure 38: Voltage Profiles – Way 4

4.1.4.2.3 Feeder Way 3

Again, the escalation process is carried out. The peak demand for 5 minutes resolution was 40 kVA and the aggregated demand from Elexon profiles is 27.7 kVA, therefore the factor is 1.44 (40 kVA / 27.7 kVA). The profile after the escalation process is in Figure 39.

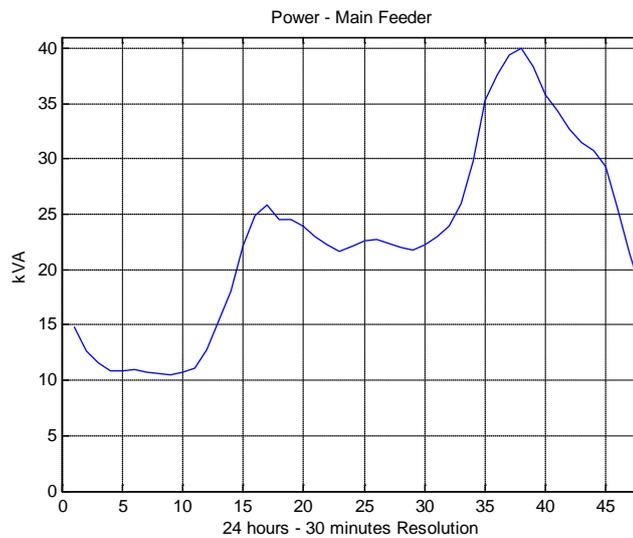


Figure 39: Aggregated Profile after the escalation – Way 3

The ADMD is 1.29 kVA and it is equal to the peak demand for each customer connected to this feeder. Thus, there are not customers modelled with peak demand higher than 1.29 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 40. The loads are sorted from the transformer to the most remote load. All of the voltage profiles have similar shape, but the voltage drop is deeper for the loads further from the transformer.

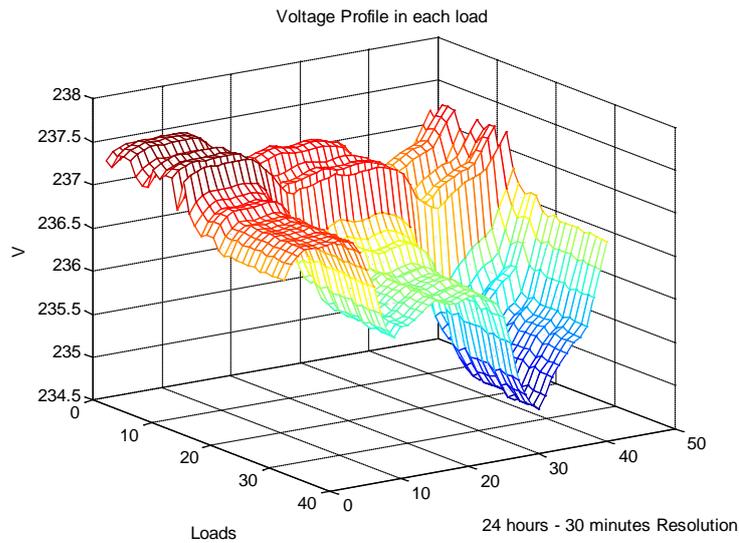


Figure 40: Voltage Profiles – Way 3

4.1.4.2.4 Feeder Way 2

The escalation process is also developed. The peak demand for 5 minutes resolution was 80 kVA and the aggregated demand getting directly from Elexon profiles is 63.2 kVA, therefore the factor is 1.26 (80 kVA / 63.2 kVA). The aggregated profile after the escalation process is in Figure 41.



Figure 41: Aggregated Profile after the escalation – Way 2

In this feeder, the ADMD is equal to 1.14 kVA and it is equal to the peak demand for each customer connected to this feeder, which is not quite realistic, indeed under this approach there is not one with consumption higher than 1.14 kVA.

The voltage profiles for each load in the feeder are indicated in Figure 42. The loads are sorted from the transformer to the most remote load.

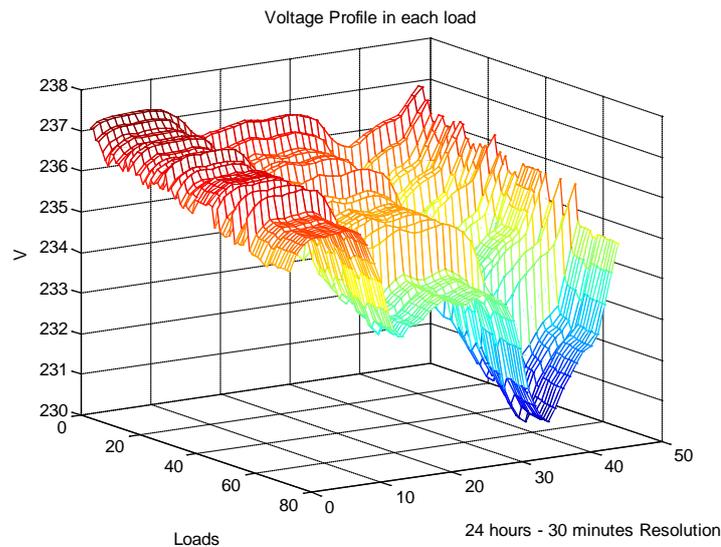


Figure 42: Voltage Profiles – Way 2

4.1.4.3 Discussion

From the comparison of both (load profile) approaches the following comments can be drawn:

1. The half hourly profile does not appropriately show the peak demand and the effects of these peaks on the network.
2. The consideration of average profiles can underestimate the impacts, because the peak demand in each customer is not modelled. In all of the feeders studied the peak demand for a single house was smaller than 1.3 kVA in the Elexon profile. However, in practice, one house can have a peak demand bigger than that (in fact just a kettle plus a washing machine can consume more than 1.5 kW together).
3. The impacts on voltage can be underestimated in the Elexon profiles because they are not modelling the real peaks in each household. This effect is easy to observe in the longest feeder (Way 2) by comparing the voltage profiles with the two approaches. In the 5 minutes resolution profile the minimum voltage is about 228 V and there are many voltages below 230 V (Figure 43 left). In contrast, for the Elexon case the minimum voltage is about 230 V (Figure 43 right).

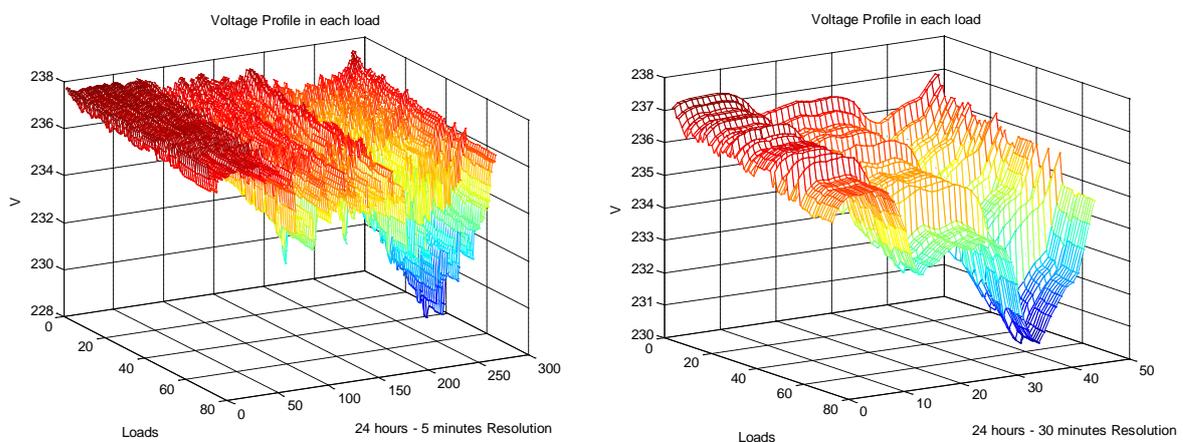


Figure 43: Voltage Profile Comparison – Way 2

5 Conclusions

Deliverable 1.3 "Creation of non-validated computer-based models of monitored and generic LV networks ready to be used for planning studies" has been successfully completed.

To show the readiness of the Dunton Green network model, initial studies were carried out. In particular, a comparison between the utilisation of average (or diversified) profiles (from Elexon data) and realistic residential profiles (from a computational model) was performed. This exercise successfully demonstrated the capabilities of the model.

The methodology to create the computer-based network models has been successfully tested. The University of Manchester is ready to apply it to the rest of the LV networks to be monitored in the project. However, in order to align our work to the original schedule it is crucial that ENWL provide all the necessary data in a timely manner.

6 Appendix

Using the information received it is possible to create a structured set of files that allow the LV networks to be represented in OpenDSS format. The files automatically created are:

- Lines.txt
- Loads.txt
- LoadShapes.txt
- LineCode.txt
- Transformers.txt
- Monitors.txt

As an example, the next figures show snapshots of each of the files for way number 2 of Dunton Green.

```

Lines - Notepad
File Edit Format View Help
New Line.LINE1 Bus1=1 Bus2=2 Linecode=4c_70 Length=1.6321 Units=m
New Line.LINE2 Bus1=2 Bus2=3 Linecode=4c_70 Length=0.10717 Units=m
New Line.LINE3 Bus1=3 Bus2=4 Linecode=4c_70 Length=0.117 Units=m
New Line.LINE4 Bus1=4 Bus2=5 Linecode=4c_70 Length=0.091214 Units=m
New Line.LINE5 Bus1=5 Bus2=6 Linecode=4c_70 Length=0.14414 Units=m
New Line.LINE6 Bus1=6 Bus2=7 Linecode=4c_70 Length=11.806 Units=m
New Line.LINE7 Bus1=7 Bus2=8 Linecode=4c_70 Length=0.24604 Units=m
New Line.LINE8 Bus1=8 Bus2=9 Linecode=4c_70 Length=0.1472 Units=m
New Line.LINE9 Bus1=9 Bus2=10 Linecode=4c_70 Length=0.22532 Units=m
New Line.LINE10 Bus1=10 Bus2=11 Linecode=4c_70 Length=0.26642 Units=m
New Line.LINE11 Bus1=11 Bus2=12 Linecode=4c_70 Length=0.2826 Units=m
New Line.LINE12 Bus1=12 Bus2=13 Linecode=4c_70 Length=0.41208 Units=m
New Line.LINE13 Bus1=13 Bus2=14 Linecode=4c_70 Length=7.3507 Units=m
New Line.LINE14 Bus1=14 Bus2=15 Linecode=4c_70 Length=12.0736 Units=m
New Line.LINE15 Bus1=15 Bus2=16 Linecode=4c_70 Length=2.6857 Units=m
New Line.LINE16 Bus1=16 Bus2=17 Linecode=4c_70 Length=0.66612 Units=m
New Line.LINE17 Bus1=17 Bus2=18 Linecode=4c_70 Length=0.44967 Units=m
New Line.LINE18 Bus1=18 Bus2=19 Linecode=4c_70 Length=0.53827 Units=m
New Line.LINE19 Bus1=19 Bus2=20 Linecode=4c_70 Length=0.9881 Units=m
New Line.LINE20 Bus1=20 Bus2=21 Linecode=4c_70 Length=0.72993 Units=m
New Line.LINE21 Bus1=21 Bus2=22 Linecode=4c_70 Length=0.45427 Units=m
New Line.LINE22 Bus1=22 Bus2=23 Linecode=4c_70 Length=0.827 Units=m
New Line.LINE23 Bus1=23 Bus2=24 Linecode=4c_70 Length=1.874 Units=m
New Line.LINE24 Bus1=24 Bus2=25 Linecode=4c_70 Length=10.5218 Units=m
New Line.LINE25 Bus1=25 Bus2=26 Linecode=4c_70 Length=4.3326 Units=m
New Line.LINE26 Bus1=25 Bus2=27 Linecode=2c_16 Length=10.1369 Units=m
New Line.LINE27 Bus1=26 Bus2=28 Linecode=4c_70 Length=3.1196 Units=m
New Line.LINE28 Bus1=27 Bus2=29 Linecode=2c_16 Length=0.60232 Units=m
New Line.LINE29 Bus1=27 Bus2=30 Linecode=2c_16 Length=4.6018 Units=m
New Line.LINE30 Bus1=28 Bus2=31 Linecode=4c_70 Length=4.7735 Units=m
New Line.LINE31 Bus1=29 Bus2=32 Linecode=2c_16 Length=0.36641 Units=m
New Line.LINE32 Bus1=30 Bus2=33 Linecode=2c_16 Length=2.2551 Units=m
New Line.LINE33 Bus1=31 Bus2=34 Linecode=4c_70 Length=6.4445 Units=m
New Line.LINE34 Bus1=32 Bus2=35 Linecode=2c_16 Length=0.27771 Units=m
New Line.LINE35 Bus1=34 Bus2=36 Linecode=2c_4 Length=0.27536 Units=m
New Line.LINE36 Bus1=34 Bus2=37 Linecode=4c_70 Length=1.1841 Units=m
New Line.LINE37 Bus1=35 Bus2=38 Linecode=2c_16 Length=0.10878 Units=m
New Line.LINE38 Bus1=36 Bus2=39 Linecode=2c_4 Length=0.22361 Units=m
New Line.LINE39 Bus1=37 Bus2=40 Linecode=4c_70 Length=9.3527 Units=m
New Line.LINE40 Bus1=37 Bus2=41 Linecode=2c_16 Length=7.9128 Units=m
New Line.LINE41 Bus1=38 Bus2=42 Linecode=2c_16 Length=0.173 Units=m
New Line.LINE42 Bus1=39 Bus2=43 Linecode=2c_4 Length=0.14142 Units=m
New Line.LINE43 Bus1=40 Bus2=44 Linecode=4c_70 Length=3.8759 Units=m
New Line.LINE44 Bus1=41 Bus2=45 Linecode=2c_16 Length=0.52612 Units=m
New Line.LINE45 Bus1=42 Bus2=46 Linecode=2c_16 Length=0.31186 Units=m
New Line.LINE46 Bus1=43 Bus2=47 Linecode=2c_4 Length=0.14241 Units=m
New Line.LINE47 Bus1=44 Bus2=48 Linecode=4c_70 Length=0.35526 Units=m
New Line.LINE48 Bus1=44 Bus2=49 Linecode=4c_35 Length=0.59758 Units=m
New Line.LINE49 Bus1=45 Bus2=50 Linecode=2c_16 Length=0.18111 Units=m
    
```

Figure 44: Lines File for OpenDSS


```

LineCode - Notepad
File Edit Format View Help
New LineCode..4_PSC R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.007 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.022 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.0225 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.04 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.4 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.16 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.2C_.25 R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.35_SAC_XSC_TP R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.3C_95_SAC_ASN R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4_PC R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.4_PSC R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.4_XC_TP R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.4_XSC R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.4_XSC_TP R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
New LineCode.4C_.06 R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4C_.1 R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4C_.35 R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4C_.5 R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4C_.5_AC R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.4C_70 R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.95_PC R1=0.322 X1=0.074 R0=1.2822 X0=0.125 C1=0 C0=0 Units=km
New LineCode.Cu R1=0.868 X1=0.077 R0=0.910 X0=0.077 C1=0 C0=0 Units=km
  
```

Figure 47: Line Code File for OpenDSS

```

Transformers - Notepad
File Edit Format View Help
New Transformer.TR1 Buses=[SourceBus 1] Conns=[Delta wye] kvs=[11 0.412] kvAs=[800 800] XHL=1
  
```

Figure 48: Transformer File for OpenDSS

```

Monitors - Notepad
File Edit Format View Help
New Monitor.LINE1_PQ_vs_Time Line.LINE1 1 Mode=1
New Monitor.LINE1_VI_vs_Time Line.LINE1 1 Mode=0
New Monitor.LINE2_PQ_vs_Time Line.LINE2 1 Mode=1
New Monitor.LINE2_VI_vs_Time Line.LINE2 1 Mode=0
New Monitor.LINE3_PQ_vs_Time Line.LINE3 1 Mode=1
New Monitor.LINE3_VI_vs_Time Line.LINE3 1 Mode=0
New Monitor.LINE4_PQ_vs_Time Line.LINE4 1 Mode=1
New Monitor.LINE4_VI_vs_Time Line.LINE4 1 Mode=0
New Monitor.LINE5_PQ_vs_Time Line.LINE5 1 Mode=1
New Monitor.LINE5_VI_vs_Time Line.LINE5 1 Mode=0
New Monitor.LINE6_PQ_vs_Time Line.LINE6 1 Mode=1
New Monitor.LINE6_VI_vs_Time Line.LINE6 1 Mode=0
New Monitor.LINE7_PQ_vs_Time Line.LINE7 1 Mode=1
New Monitor.LINE7_VI_vs_Time Line.LINE7 1 Mode=0
New Monitor.LINE8_PQ_vs_Time Line.LINE8 1 Mode=1
New Monitor.LINE8_VI_vs_Time Line.LINE8 1 Mode=0
New Monitor.LINE9_PQ_vs_Time Line.LINE9 1 Mode=1
New Monitor.LINE9_VI_vs_Time Line.LINE9 1 Mode=0
New Monitor.LINE10_PQ_vs_Time Line.LINE10 1 Mode=1
New Monitor.LINE10_VI_vs_Time Line.LINE10 1 Mode=0
New Monitor.LINE11_PQ_vs_Time Line.LINE11 1 Mode=1
New Monitor.LINE11_VI_vs_Time Line.LINE11 1 Mode=0
New Monitor.LINE12_PQ_vs_Time Line.LINE12 1 Mode=1
New Monitor.LINE12_VI_vs_Time Line.LINE12 1 Mode=0
New Monitor.LINE13_PQ_vs_Time Line.LINE13 1 Mode=1
New Monitor.LINE13_VI_vs_Time Line.LINE13 1 Mode=0
New Monitor.LINE14_PQ_vs_Time Line.LINE14 1 Mode=1
New Monitor.LINE14_VI_vs_Time Line.LINE14 1 Mode=0
New Monitor.LINE15_PQ_vs_Time Line.LINE15 1 Mode=1
New Monitor.LINE15_VI_vs_Time Line.LINE15 1 Mode=0
New Monitor.LINE16_PQ_vs_Time Line.LINE16 1 Mode=1
New Monitor.LINE16_VI_vs_Time Line.LINE16 1 Mode=0
New Monitor.LINE17_PQ_vs_Time Line.LINE17 1 Mode=1
New Monitor.LINE17_VI_vs_Time Line.LINE17 1 Mode=0
New Monitor.LINE18_PQ_vs_Time Line.LINE18 1 Mode=1
New Monitor.LINE18_VI_vs_Time Line.LINE18 1 Mode=0
New Monitor.LINE19_PQ_vs_Time Line.LINE19 1 Mode=1
New Monitor.LINE19_VI_vs_Time Line.LINE19 1 Mode=0
New Monitor.LINE20_PQ_vs_Time Line.LINE20 1 Mode=1
New Monitor.LINE20_VI_vs_Time Line.LINE20 1 Mode=0
New Monitor.LINE21_PQ_vs_Time Line.LINE21 1 Mode=1
New Monitor.LINE21_VI_vs_Time Line.LINE21 1 Mode=0
New Monitor.LINE22_PQ_vs_Time Line.LINE22 1 Mode=1
New Monitor.LINE22_VI_vs_Time Line.LINE22 1 Mode=0
New Monitor.LINE23_PQ_vs_Time Line.LINE23 1 Mode=1
New Monitor.LINE23_VI_vs_Time Line.LINE23 1 Mode=0
New Monitor.LINE24_PQ_vs_Time Line.LINE24 1 Mode=1
New Monitor.LINE24_VI_vs_Time Line.LINE24 1 Mode=0
New Monitor.LINE25_PQ_vs_Time Line.LINE25 1 Mode=1
    
```

Figure 49: Monitors File for OpenDSS