Scottish & Southern Electricity Networks

THAMES VALLEY VISION

New Thames Valley Vision
Learning Outcome Report

Overall Proven Benefits – Financial and Customer Service

Bracknell Forest Council · ea technology · DNV·GL · GE · Honeywell · University of Reading · University of Oxford

Scottish & Southern Electricity Networks

Scottish and Southern Electricity Networks (SSEN) is the new trading name of Scottish and Southern Energy Power Distribution (SSEPD), the parent company of Southern Electricity Power Distribution (SEPD), Scottish Hydro Electricity Power Distribution (SHEPD) and Scottish Hydro Electricity Transmission. SEPD remains the contracted delivery body for this LCNF Project.

Prepared by

Document Owner(s)	Project / Organisation Role
Gideon Evans	Project Manager
Nigel Bessant	Project Delivery Manager

Contents

1 Summary

1.1 Criteria 9.8(a) Part 8

Successful Delivery Reward Criteria 9.8 (a)

Criterion:

Prepare final reports on the trials carried out on the subjects listed in "Evidence 9.8" as well as an end of project report

Evidence:

(8) Overall Proven Benefits (both financial and customer service)

(Method 1, Learning Outcomes 2.4 and 2.6)

• Use of modelling to support DNO investment decisions

• Use of modelling to support others (customers, industry, local government)

SSEPD confirms that this criterion has been met.

This document provides details of the Network Modelling Environment and the way in which it can be used to model the network using customer energy profile data, and assess the impact of low carbon technologies when they are connected to the network by customers. Be assessing the demands on the network in a more detailed and accurate manner than was possible with traditional methods, in particular the use of After Diversity Maximum Demand (ADMD) methodology, it is expected that greater confidence can be gained in the modelling outputs, and this will allow a more detailed assessment of the network locations where headroom is identified to be limited (or exceeded). This will support investment decisions that can be closely targeted. As confidence in forecasts grows it would be expected that the timing of the required reinforcement works can also be matched more closely to the real need.

This report presents the findings identified in line with the evidence criteria specified for the Successful Delivery Reward Criteria (SDRC).

It is confirmed that:

- The Network Modelling Environment is described in terms of what it can do and the data requirements to facilitate its operation.

- The modelling techniques are applied and verified on real networks.
- Network modelling is improved with the use of energy profiles.
- The impact of disruptive technology penetration (eg electric vehicle charging) is modelled and assessed.
- Virtual monitoring (buddying) can be used effectively in the modelling environment.
- Forecasting methodologies can be used in conjunction with the modelling environment.
- The Network Modelling Environment provides both direct and indirect benefits to customers and industry.
- The relationship between the DNO and local authorities can be effectively supported using the Network Modelling Environment.

1.2 Background

The take up of low carbon technologies such as electric vehicles and solar panels by customers is both uncertain and potentially disruptive to the low voltage network. Existing methodologies for assessing the capacity of the network such as calculations of After Diversity Maximum Demand (ADMD) have worked well for assessing traditional loads, but are not suited to the detailed assessment of the peak demands expected from electric vehicle charging. For this purpose a better understanding of the profile of energy usage is required, together with the ability to model the demands on the network taking energy profiles into account.

The NTVV project has established a Network Modelling Environment (NME) which is based on the existing SSEPD Graphical Information System (GIS) network data, and linked to a modelling tool that is well suited to calculating electrical network parameters using energy profiles. It is intended that this NME can be loaded with energy profiles representing various scenarios from current smart meter data if available, or forecast loads taking into account low carbon technology uptake scenarios.

In reality, the roll out of smart meters by Energy Suppliers was expected to lag the need for data on the project, and it was recognised that alternative mathematical techniques could be used to create a meaningful energy profile for every customer (buddying) which could then be used in the model.

An improved modelling tool loaded with relevant energy profile data should give confidence to a DNO that calculated headroom at each point on the network is a good assessment of the loading of the network, and when presented in a red / amber / green type of comparison with the capacity of the network, this will allow targeted investment decisions to be made. Further, the modelling tool can be used to asses the proposed solutions to recognised network problems, and will facilitate the planning for particular scenarios.

SDRC 9.8 (a Part 8) was established to acknowledge the clear focus given to the outcome of trials using the NME, and how these will assist a DNO in making investment decisions. Trials have been established to verify the NME, use of the NME with energy profiles, use of the NME with profiles that represent disruptive technology penetration, and the application of short term forecasts.

The use of modelling is also considered in terms of support to customers, industry and local government, and in particular whether and how the modelling can best interact with town planning systems and processes.

1.3 Link to Methods and Learning Outcomes

Method 1 as defined for NTVV (see SET203 New Thames Valley Vision bid submission) proposes the use of modelling using individual customer energy profiles as a means to improve the accuracy of modelling in the context of customers adopting new technologies such as electric vehicles and solar PV that will clearly have an impact on the network. There is a focus on understanding the existing headroom on the network, including compliance with voltage limits, assessing the level of technology uptake that could be accepted by the network taking the capacity and voltage limits into account, and then considering the impact on the network of various uptake scenarios.

Successful completion of **Learning Outcome 2.4** requires an understanding of the output of the modelling in terms of confidence that it can be used to correctly inform decisions regarding capital spend (CAPEX) and operational spend (OPEX) requirements, taking into account low carbon loads and projections regarding future take up. An assessment of the scale of possible low carbon technology take up with out requiring significant investment is also valuable.

Successful completion of **Learning Outcome 2.6** requires improved modelling to inform existing procedures in terms of which parameters to consider and the thresholds that are relevant in terms of correct and reliable operation of the network.

The establishment of the NME has been previously recorded in **SDRC 9.6 Evidence Report** and associated appendices.

2 Use of Modelling to Support DNO Investment Decisions

2.1 The Network Modelling Environment

The Network Modelling Environment has been established as a common source of information about the low voltage network in the project area (Bracknell) and it includes the power analysis tool (Cymdist). A full description of the components of the NME, the sources of data, the IT architecture, the link to the Distribution Management System (DMS) and the reports that can be obtained are described in the **SDRC 9.6 Evidence Report (Low Voltage Network Modelling Environment Built, Installed and Commissioned).** See also Figure 1 below.

Figure 1 The Network Modelling Environment

As a summary, The NME consists of two main tools, Smallworld Electric Office and Cymdist. Smallworld Electric Office is a geospatial asset management platform; it holds the data about the network including connectivity, geographic location as well as the types of network components and their sizes. The primary purpose of this tool is to allow users to visualise the low voltage network. Cymdist is a power analysis tool that can work in conjunction with Smallworld Electric Office; it receives sections of the network as requested by users, and performs analysis calculations as desired. It holds the electrical characteristics of all the electrical components of the network. It is closely linked with a further subcomponent called Energy Profile manager; this stores energy profiles for all points on the network and allows these to be used in the power analysis calculations.

The primary source of low voltage network data in the NME was the existing GIS system (Smallworld Version 3.1). This has been migrated into the NME and for the lifecycle of the project it will be kept up to date in line with changes made to the real network (eg new connections, diversions, cable overlays etc.). This was supplemented with data about demand and generation points from SSEPD's Supply Information Management System (SIMS) and transformer rating data from the Plant and Cable Asset Register (PLACAR). Electrical characteristics for cables, conductors and other equipment were derived from SSEPD's document library.

In each case the data was assessed and prepared for migration to the NME. The data preparation is summarised:

Learning Points – Data Preparation		
No	**Topic**	**Learning**
1	GIS Data - Connectivity	The network information held in the existing GIS system fulfils the objectives for which it was recorded and displayed (ie to give the correct geospatial position of cables shown outside of substations). The recording of the mains cable connectivity is less certain than the position of the cables, but this connectivity is crucial for the correct analysis of power flows or nodal voltages. Effort spent correcting the connectivity of the mains, particularly at the distribution substations, is fully justified. Other instances of connectivity problems (eg multiple mains in close proximity with uncertainty as to which customers are connected to which) are very difficult to identify correctly; such situations should be noted (so that the power analysis can be interpreted accordingly)
2	GIS Data – Cable Sizes	Where the type of cable is missing (stated as "unknown"), the power analysis tool will be unable to operate. A type of cable has to be inserted for all cables. For mains cables an algorithm can be applied to be run as an IT function.

Scottish & Southern Electricity Networks

3	GIS Data – Service Cables	Service cables were not recorded for many years, and hence there are many gaps in the available data. It was found that: **Position** – service cables can be applied in an automated manner at the time of the initial migration (straight line from end point to nearest main). **Type** – Standard cable types can be applied (eg 35sqmm single core aluminium). **Phase allocation** – can be applied at initial migration to an agreed algorithm (eg RYB, BYR,...) None of these are perfect, but each allows the power analysis function to operate in a credible manner.
4	SIMS - Matching to Address Base	Each end point needs to be matched to an address point so that energy profiles can be correctly allocated. In the project an 80% address match average was achieved by automated means. Addresses that have not matched successfully are visible and a user is aware of these. Running studies where the address match rate is less than 80% is considered inadvisable, and fixing the missing 20% can be disproportionately onerous. In reality, the hardest addresses to match are generally commercial properties (large units on industrial estates) or rural properties (e.g. Rose Cottage on The Street); where it is necessary to run a power flow analysis at one of these locations, correcting the address matching on a targeted basis is essential.

5	PLACAR	The main data of interest in PLACAR is the transformer rating; this is generally good data for ground mounted substation; for pole mounted substation there was typically no rating or site location number. An artificially created location number was generated for the project, but any future scaled up process should include for the agreement of a numbering strategy (e.g. use of wayleave number, OS co-ordinate related number etc.). The transformer size has had to be assumed from some indicative criteria (assessment of GIS information allows some interpretation of number of HV and LV phases, number of customers connected and knowledge of standard sizes); this has allowed the NME to be populated with credible data, but it is accepted that the uncertainty will reflect in the outcome of any studies.
6	Electrical Characteristics	For missing values a corrective assumption was applied manually, re-assessing actual cable types recorded in the GIS or identifying values for rarely used cable types.

2.2 Verification of Modelling Techniques for Application on Real DNO Networks

Before the NME can be used to support investment decisions, confidence needs to be established that it functions correctly and as would be expected of a network power analysis tool. This was achieved by assessing the NME in a number of ways.

2.2.1 Comparison with WinDEBUT

WinDEBUT is a power analysis tool that is already in widespread use by existing planning teams to assess prospective new connections in terms of the impact that they will have on the existing network. The tool is designed to calculate loadings based on the traditional After Diversity Maximum Demand (ADMD) methodology.

The functionality of the NME was compared with WinDEBUT by creating a simple section of network in both systems and running a power flow analysis study on each. This analysis is described fully in **Appendix 1 The Network Modelling Environment, Section 4**.

For this analysis it was necessary to create a network model within WinDEBUT, and then define the loads to be applied as well as the source voltage. A power analysis study could then be run in WinDEBUT to identify the loading of each section and the voltage drop at each node.

The same section of network was then created in the NME with matching loads and source voltage applied. Note that the load had to be converted to a load profile for the period of the study (1 full day).

Taking account of the different calculating methodologies, identical results would not be expected, but a reasonable assessment of the effectiveness of the NME would be expected to be derived from being able to explain any differences.

Both the WinDEBUT study and the Network Modelling Environment study showed no issues with the thermal loading of the cables, which would be expected for the particular network selected. It was found that the nodal voltage drop results from WinDEBUT and the NME differed by less than half a percent at both service points on the feeder when compared with the source voltage of the feeder. This is statistically insignificant enough for the results from both systems to be judged as valid and of equal worth, and therefore it can be stated that the results from the NME can be taken as seen with confidence that they are representative of the existing network.

2.2.2 Use of the NME to assess New Connections

Traditional functions carried out by an electrical planner in the process of identifying the feasibility of connecting a new load to a section of network include viewing the network, annotating a map that includes the network with the proposed new service cable, calculating the voltage drop along the proposed service cable and assessing whether adding the new service would cause unacceptable levels of load on the network. These are precursors to the costing of the works and despatch of a quotation to the customer, all of which are tightly controlled to ensure that the customer has a confirmed response in the shortest possible time.

Traditionally, the hardest part of the process is that of gathering electrical information to be able to carry out a power flow analysis; the use of the NME should make this easier as both the GIS geographical and connectivity information are held in one place together with the electrical characteristics. Adding a new service (creating a “design”), assigning a load profile and running a study are fundamentally quicker and easier. In a direct assessment of this process it was found that once the background network data had been imported into the NME and was available for use then the time taken to start a new design and make the necessary changes to the network was comparable to using the current WinDEBUT system. The network planning staff who participated in the NME demonstration all commented that they would initially find the new system more complicated to use but that they could see already that the NME would save them time in the production of quotes for new connections and improve the accuracy of their decisions as to whether a new connection was feasible. They did have some concerns about the speed of the system in running the studies compared with the current WinDEBUT system, but when it was explained that the NME was capable of calculating the cable loading levels and nodal voltages across a whole substation and for a series of dates, not just for a single point in time, they could see that these features would provide sufficient benefit to them to justify the time taken to run a study. It was also made that current speed of operation reflects the project resources, and deployment for business as usual would be subject to detailed analysis of IT resources required to facilitate simultaneous use across multiple users.

It was recognised that this process is dependent upon the available profiles being accurately assigned to existing end points, correct matching of end points between the network and the map, and the phase allocation strategy. All of these will influence the absolute correctness of the outcome, but the point of the NME is that these “assumptions” are already made and held in the NME so that the user can proceed with a quick and meaningful analysis; the same underlying assumptions have to be made by the traditional approach, but the user has to decide on each of these individually. This is time consuming and leads to a further consideration of consistency between users.

2.2.3 Giving Visibility to Network Stress Points

The network is constrained by both thermal limits (capacity of the cables to carry the load current) and by voltage limits (defined as 230V +10% -6% at the customer’s terminal). Traditional modelling tools allow the loading and voltage at selected points on the network to be calculated, but to do this they require the section of the network to be manually entered together with cable types and electrical characteristics. For modest sections of the network this is practical but time consuming.

In the NME, with the connectivity, cable types, electrical characteristics and network loading all held in one place, it is easy to run a study for a larger area (e.g. all feeders on a substation, or several substations). To improve the confidence of a study, it was decided that each base study should be supported by additional studies with the same criteria, but with additional dummy loads added at the ends of each branch of the network being studied. This dummy load is first assigned to a positive profile, representing additional load, and then assigned a negative profile representing generation. Effectively two additional studies are run for each branch on the network. The output of such studies in the NME is presented both numerically and also geographically by colouring up the circuits with a red, amber or green coding.

The colours are defined as:
Green capacity limit (or voltage threshold) not breached in either the base confidence case or any of the positive or negative confidence cases
Amber capacity limit (or voltage threshold) not breached in the base confidence case but breached at some point in at least one of the positive or negative confidence cases
Red capacity limit (or voltage threshold) breached in the base confidence case.

In an assessment of this process, load profiles were created and applied to all customers fed from a substation. The profiles were chosen to be modest such that they would not intentionally stress a typical feeder from a typical substation. It was expected that, when analysed, the feeder would show up in green. A process of doubling and tripling the load profiles was then applied, with further power flow studies being carried out. When the load reached the capacity limit of the cables, the relevant sections of overloaded cables could be seen to go amber.

The results from the studies run on the “standard” profiles and multiples thereof can be seen in **Appendix 1 The Network Modelling Environment, Section 3**. The cable loading and nodal voltage drop studies were run on three substations – Julius Hill, Radcliffe Way and Walsh Avenue – and the NME was able to show that differing levels of load produced correspondingly different results. In particular, it was clearly shown which areas of the network were under stress when these particular load profiles were allocated to the properties.

As for other studies, the NME has known assumptions about phase allocation, and consideration needs to be given to the proportion of properties on the feeder under analysis that have been correctly address matched. Every property on the feeder that has not been matched represents “missing load”, and this would either need to be compensated for, or allowance made that the outcome of the study is optimistic. For the project it is recognised that feeders will be targeted for analysis where the address matching is high, or extra effort applied to match addresses manually where necessary. There is sufficient project resource to manually match all addresses that are required for the project, but this is not sufficient to scale to every property in Brackell that was not matched through the automated process (approximately 3400 across the 325 substations where monitoring was intended to be installed). SSEPD business as usual teams have recognised the importance of this issue for a number of purposes, and it is proposed that SSEPD will move from using Ordnance Survey Address Layer 2 (as used within the NME) to Ordnance Survey Address Base Premium data; this includes the use of Unique Property reference Numbers (UPRNs), and allows the linking of properties that may be excluded from postal address databases but likely to have a service connection (e.g. churches, bus shelters etc.). A future deployment of the NME would not therefore be constrained by this issue, and it will be possible to link much more readily to smart meter data.

Learning Points – Effectiveness of the NME		
No	**Topic**	**Learning**
1	Comparison with WinDEBUT	WinDEBUT calculates circuit loading using ADMD values. The comparison of calculated values will therefore be expected to be different, but for a comparable load, the calculated values would expect to be proportionate. The results from the NME showed values that were statistically similar to the results from the WinDEBUT modelling tool, and so the NME can be deemed to be able to produce accurate load flow analysis of the network.

2	Assessing new service connections	Provided the NME has been established with relevant load profiles (actual smart meter readings or suitable buddied profiles), the NME can be used to calculate the impact of an additional service cable being connected (to serve a new customer load). The impact in terms of both circuit loading (thermal constraints) and voltage can be assessed very quickly with green, amber or red visualisation of the outcome with appropriate consideration of confidence. Design assumptions (e.g. unknown cable types) are captured centrally rather than relying on the user making individual assumptions at the time of the study (which is the traditional approach).
3	Assessing network stress points	Provided the NME has been established with sufficiently accurate network connectivity, cable types, electrical characteristics, and customers matched to the correct points on the network, load profiles can be applied to all customers to simulate different loading scenarios. A study can then be run in the NME. The network diagram is then coloured by the NME in accordance with: **Green** capacity limit (or voltage threshold) not breached in either the base confidence case or any of the positive or negative confidence cases during the period of assessment **Amber** capacity limit (or voltage threshold) not breached in the base confidence case but breached at some point in at least one of the positive or negative confidence cases during the period of assessment **Red** capacity limit (or voltage threshold) breached in the base case during the period of assessment. In this way for each scenario the stress points on the network can be identified and assessed.

2.3 Improvement in Network Modelling Techniques using Profiles

2.3.1 Traditional Modelling – Use of ADMD

Traditional low voltage network modelling is carried out using customer load values based on After Diversity Maximum Demand (ADMD). This methodology assigns an empirically derived value (e.g. 2kVA for a customer whose property has non electric heating) to every customer of that type. These values for load can then be added to the network model as fixed values, and the model can then be run to calculate the loading value and voltage drop at each point on the network. Historically, this methodology has proved effective at assessing the domestic customer loading on the network, allowing relatively easy decision making with regard to connection requests for new loads. The end point monitoring data has been used to calculate the actual ADMD value for customers in the Bracknell area. This analysis can be seen in **Section 1 Comparison with ADMD** of **Appendix 2 Network Statistics**.

By definition, this methodology assumes that there is diversity in the load. For example, in general it is unlikely that two or more customers will turn a kettle on simultaneously; the more customers on the network the greater the effect of this diversity, and hence the logical addition of an average load per customer gives a good approximation of the total loading of the network that needs to be allowed for in the network design.

The use of ADMD is most effective for variable loads of large numbers of customers, or for smaller numbers of customers when the load is less variable. It follows that it is ineffective when there is a small number of customers and a very large variability in load, as is characteristic of EV charging. In this case, unless influenced otherwise, it is assumed that most electric vehicle owners will plug their vehicles into charge when they get home from work, and this could result in a large demand sustained for several hours, partially coincident with existing peak demand. Similarly, generation from PV is determined by the position of the sun and local cloud cover; for a particular street, and the feeder to which the properties are connected, this generation will be simultaneous at every property.

2.3.2 Modelling using Energy Profiles

The NME makes no assumptions about ADMD as it works totally with half hourly energy profiles. If relevant energy profiles are assigned to every endpoint, and assuming the model is correctly established in terms of connectivity, cable types, electrical characteristics and end point allocation, then the thermal loading and voltage drop for each half hour can be calculated. If any of these half hour values are outside of limits then the NME can draw this to the attention of the user.

Both network planning tools were assessed on the Queens Pine substation during the time period 1 November 2013 to 30 November 2013. This substation and these dates were selected following analysis of data recorded by the substation monitoring installed at this site, which indicated that the notional transformer rating was repeatedly exceeded on phase L1. A detailed analysis of the studies run on this substation is included in **Appendix 3 Improving Network Modelling Techniques Using Profiles.**

It was seen that the NME identified network loading problems that would not be recognised using an ADMD based modelling tool. Specifically it was capable of recognising issues that were not picked up by the WinDEBUT modelling tool, which showed less impact on the network both in terms of thermal overloading and voltage issues.

Both modelling tools showed results as expected from electrical theory, namely that thermal overloading of cables occurred at points close to the substation source and that voltage issues occurred at points at the ends of the feeders furthest from the substation. The precise locations of the network issues did differ in both systems; however the Network Modelling Environment showed a greater number of network excursions than the WinDEBUT tool, indicating that it had a more detailed view of the situation and was able to pick up on issues that a traditional ADMD tool would not spot.

In conclusion, as the Network Modelling Environment uses half-hourly profile data to model customer demand rather than an ADMD value, it is better able to model the effect of customer demand on the network compared to the current WinDEBUT planning tool.

Learning Points – Use of Energy Profiles to Improve Modelling		
No	**Topic**	**Learning**
1	Limitations of ADMD methodology	The loading of the low voltage network has traditionally fitted the use of After Diversity Maximum Demand (ADMD) methodology which is most effective for large numbers of customers with reasonable variability of load. The method is less effective for smaller numbers of customers with very large variability of load as is associated with low carbon technologies such as electric vehicles. The use of ADMD methodology for load calculations is likely to understate the impact of the loading on the network as the penetration of low carbon technologies increases.
2	Advantage of Energy profiles	Where relevant energy profiles are available to be loaded in to the NME it is possible to calculate the loading on the network at half hourly intervals. Each half hour can then be assessed against the current and voltage thresholds, presenting the user with a visualisation of the locations on the network where the network is stressed.

2.4 Modelling the Impact of Disruptive Technology Penetration

Electric vehicle (EV) charging, photo voltaic (PV) generation and heat pump (HP) technologies are each desirable in terms of their impact on the reduction of greenhouse gases, but collectively and in aggregation are expected to have some disruptive impacts on the low voltage network. Being able to model this impact accurately and reliably is a desirable expectation of the NME. In the previous section the point was made that the NME, when loaded with half hour energy profiles, can allow the assessment of the performance of the network, and with reasonable confidence that peak demands would be proportionately considered. It would therefore be expected that with the correct data the NME can advise a DNO of where on the network to expect an issue, including the proportion of the network affected and the extent of the impact (level of overload or voltage excursion).

This was assessed in three ways.

2.4.1 Basic Analysis

The basic analysis was primarily focussed on increasing the magnitude of the half hour profiles assigned to each customer and running studies, each time assessing whether there was a breach of loading or voltage limits. An increased loading of this type is only crudely representative of EV charging (generation) being added to the network, but this approach was quick and easy to apply, and this was intended to assess the output of the NME analysis in terms of visibility of the network issues and to a lesser extent the actual performance of the network.

The outcome of this analysis can be seen in **Appendix 4 Results of Increased Loading Studies.** For this study the actual multiplier at which each feeder from each substation went out of limits was recorded.

	Customers	Mains Cables	Service Cables	End Points
	Profiles Applied	Current	Current	Voltage
	count	Load multiplier	Load multiplier	Load multiplier
Julius Hill				
Feeder 3	8	8	5	13
Radcliffe Way		1.6	1.8	2
Feeder 1	8			
Feeder 2	40			
Feeder 4	31			
Walsh Avenue		4.5	5	5.6
Feeder 2	39			
Feeder 3	73			

The sample size of three substations is too small for conclusions about the network to be drawn, but it is noted that for increased network loading (partially representative of EV or HP take up:

1) Cable loading limits are exceeded before end point voltage limits are exceeded
2) Cables and endpoints have their limits exceeded by diverse multipliers of buddied profiles
3) No correlation can be seen between the number of customers connected on the feeder and the load profile multiplier in these samples.

A typical power flow analysis from this study can be seen in **Appendix 5 Typical Power Flow Analysis – Load Multiplier 2x**, and a typical voltage study can be seen in **Appendix 6 Typical Power Nodal Analysis – Load Multiplier 2x.** These provide detailed outputs for each circuit section and node on the network for each phase of each feeder of each substation included in the study. The results are also graphically presented in the form of network diagrams coloured in accordance with red, amber and green criteria describe above.

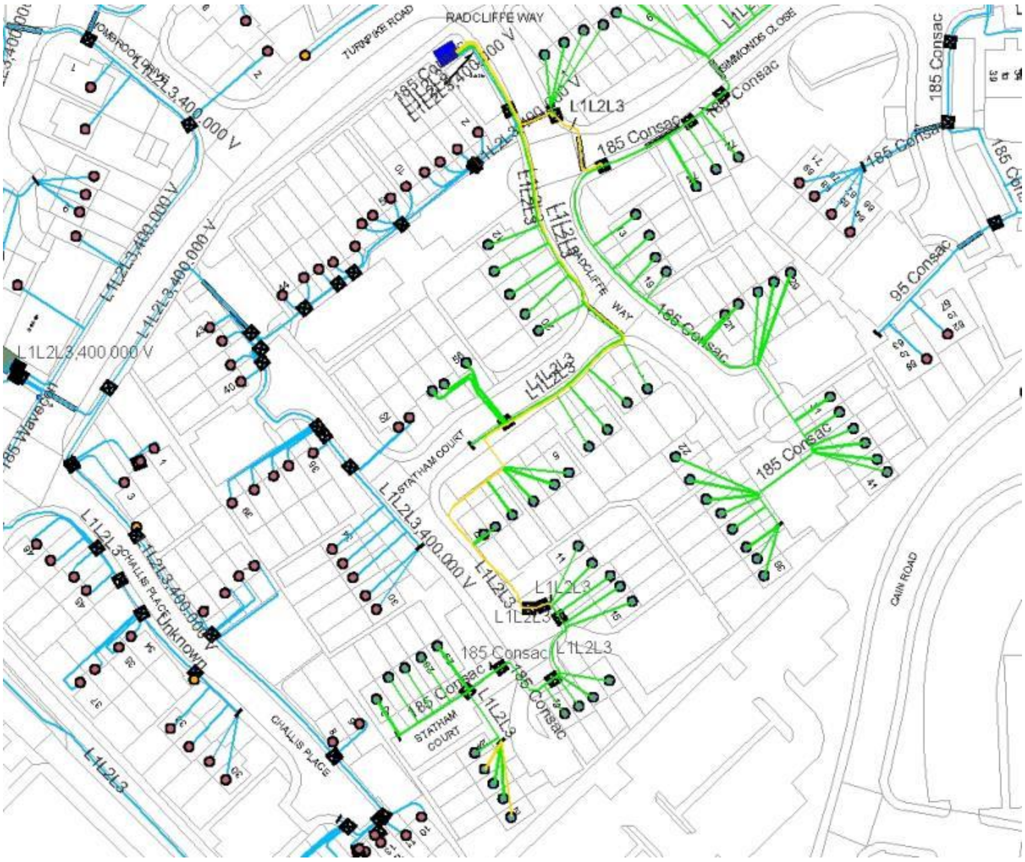

Figure 2 Radcliffe Way Feeder 4 – Amber colouring indicates capacity exceeded for some time

periods.

Further studies of this type were run using the NME to assess the reporting of the impact on the network when a cluster of customers have a significant increase in load. The affected cluster was moved down the feeder, and for each cluster position the voltage along the network assessed. This is shown in **Section 3** of **Appendix 1 The Network Modelling Environment.**

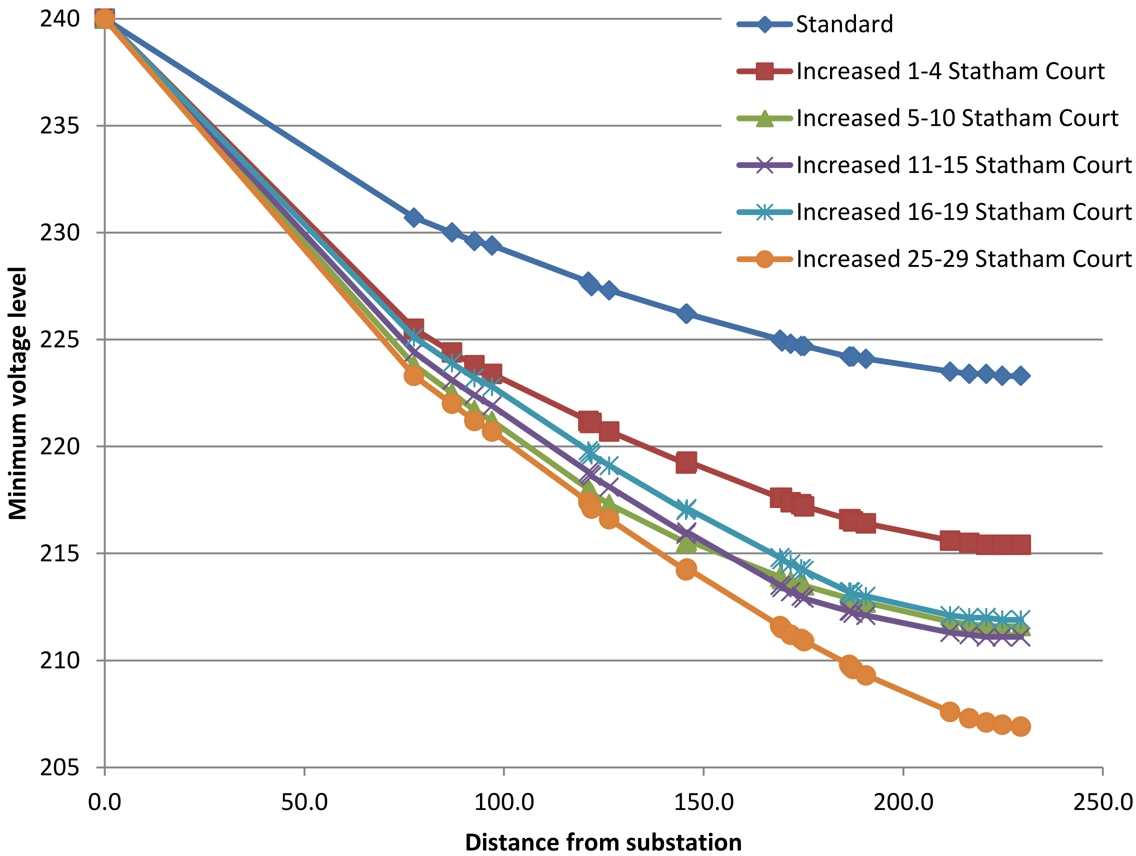

Figure 3 Graph showing the effect of moving a cluster of increased profiles along Radcliffe Way feeder 4

In this scenario, for Radcliffe Way feeder 4, the substation is next to number 1 Radcliffe Way, and higher property numbers are correspondingly further away from the substation. It can be seen that greatest impact on voltage along the feeder occurs with the increased load cluster furthest along the feeder. This is intuitively correct and this gives confidence that the NME would report appropriately if actual customer profiles that include the large loads associated with EV charging are used in the study.

2.4.2 Assessment of EV Charging

The evaluation of EV charger usage in terms of the localised effect on the network and assessment of the impact on the network as a whole is considered in detail in **SDRC 9.8(a) Part 5 EV Chargers Usage Evaluation and Issues**. The NME was extensively used to assess an EV uptake scenario; this scenario was based on the following:

- Three substations were chosen to give a typical range in terms of connected customers. These were Grange Road (43 customers connected), Horsenile Lane (199 customers connected) and Ollerton (137 customers connected). The network connectivity model was also checked to confirm that customers had been correctly assigned to the feeder circuits for these substations.

- The year of the study was chosen to be 2022 (at the end of the RIIO ED1 price control review period). To run a study for this year required the creation of a suite of long term forecast base profiles for each customer connected to the selected substations for that year.

- Running power flow analysis and nodal voltage studies for large networks over long periods is computationally expensive, and it was decided to target the analysis on selected dates, all in 2022. The days selected were:

  A Friday in January
  A Tuesday in January
  Easter in April
  A Thursday in August
  A Saturday in August

  This combination gave a reasonable seasonal spread (winter, spring and summer), a reasonable spread of days (weekday and weekend days), and a festive bank holiday.

- The scenario chosen for modelling involved the allocation of EVs to customers on a clustered basis (symbolising behaviour where residents copy their neighbours) and the DECC high EV uptake scenario (DECC Scenario 3 – “Focus on high electrification”) regarding the total proportion of customers that had acquired an electric vehicle. As this combination could lead to a high demand in a concentrated area this was regarded as the worst case scenario.

- The load profiles for electric vehicles were taken from 19 customers that participated in another EV uptake trial.

- To allow the forecasting to be carried out efficiently, a number of assumptions have had to be made. These included the assumption that no electric vehicles were already owned by customers at the start of the forecast period (2013 data), all properties were domestic, customers could charge one vehicle only, availability of suitable parking spaces was ignored, socio-economic links to EV ownership were ignored, one “slow charging” point was available at each property, and the use of public charging points was ignored. Future studies will consider these assumptions further to refine the clustering methodology, but this study was more focused on the impact of the cluster on the network.

A load flow analysis and separate nodal voltage analysis was carried out for each date and for each substation, once for the forecast base load, and once for the base load with electric vehicles added. The loading and voltages were presented in line with the red, amber and green status definitions described in **Section 2.2.3** above.

The key findings were:

Effect on Voltage

The nodal voltage analysis for all days revealed that there were no voltage drop related issues. The network operated within the defined voltage limits during all times periods.

Loading on the Network

The power flow analysis indicated that the EVs did not cause severe overloading of any parts of the network with high confidence (no additional “Red” sections). However, on some occasions the EVs increased the number of sections of the network that may become overloaded with reduced confidence (some additional “Amber” parts).

Location of Overloads

The overloaded sections were seen to be on the mains cables nearest to the substations

Customer Count

Grange Road substation which had the smallest counts of customers connected experienced no overload. It would be logical that smaller low voltage networks with fewer customers will experience fewer loading problems as they are likely to have more headroom available in their feeders.

Seasonality

At Horseneile Lane substation it was observed that the overloading in the Easter (April) and summer dates is significantly worse than for the winter dates. It is noted that the cable ratings are lower in the spring and summer than in the winter (thermal capacity is less due to higher air temperature) so for an equivalent load profile it is more likely that the rating limit is reached in these periods. It is therefore reasonable to conclude that the impact of EVs could be higher during the spring and summer.

2.4.3 Use of Smart Analytics

Attention has already been drawn to the fact that the effective use of the modelling environment requires it to be loaded with relevant profiles for each endpoint. Uncertainty remains as to the future availability of half hourly end point data, and this means that the modelling of the actual loading of the network will need to be modelled, both in its current state and with future scenarios of take up of low carbon technologies.

For the project 250 customer end points were fitted with monitoring equipment to provide actual data for analysis. These lead to a number of areas of smart analytic assessment:

- Allocation of the 250 individual customer end points to categories relating to the energy usage behaviour **(See SDRC 9.5(a) Characterisation)**
- Buddying the unmetered customers (over 30000 off) to metered end points (250 off) by assigning unmetered customers to the identified categories. **(See SDRC 9.5(c) Aggregation)**
- Forecasting end point loading based on short, medium and long term

considerations **(See SDRC 9.5(b) Forecasting)**

- Aggregating of end point loading as a means to assess the network, and potentially reduce the need for substation monitoring and end point monitoring. **(See SDRC 9.5(c) Aggregation)**

The creation and loading of end point energy profiles into the NME is crucial to the use of the NME as a tool to support business as usual uses for the NME. To support this exchange a clearly defined data format was agreed, and the use of a common server and file structure has been established between project partners. With these arrangements established it is now possible to model the impact of disruptive technologies with profiles generated using the smart analytic techniques. While this aspect remains as work in progress to the end of the project key aspects are described in **Sections 2.5** and **2.6** below.

Learning Points – Modelling the Impact of Disruptive Technology Penetration		
No	**Topic**	**Learning**
1	Basic Analysis	The NME has been shown to be capable of calculating, reporting and visually presenting the locations on the network that are adversely affected by disruptive technology penetration. This is particularly with regard to the capacity of circuits and the voltage limits that apply at the customer's terminals.
2	Assessment of EV Charging	The NME has been used to assess the impact of electric vehicle charging; this is reported in detail in **SDRC 9.8(a) Part 5**. For the "worst case" scenario studied, based on the year 2022 and DECC Scenario 3 for EV uptake, key findings were that the • Voltage limits were not breached; • Partial overloading was observed in two of the three substation networks studied; • The cable sections of the feeder cables overloaded were most likely to be the ones nearest to the substation; • Feeder circuits with a smaller count of customers may have more headroom and are less vulnerable to overloading; • Feeder circuits are more likely to be vulnerable to overloading in the spring and summer compared to the winter.
3	Use of Smart Analytics	The effective use of the NME completely depends upon the provision of relevant energy profiles. These need to be created as forecasts or determined for each customer in line with a categorisation and buddying strategy, and then loaded into the NME to an agreed format.

2.5 Use of Modelling With Forecasts (Short, Medium and Long Term)

The University of Reading and University of Oxford teams have created a number of short, medium and long term forecasting algorithms.

The short term forecasting algorithms established **(See SDRC 9.5(b) Forecasting)** are currently being further refined to take into account other factors such as temperature and humidity. The most recent report describes the seasonal impact on short term forecasting algorithms and concludes that the error increases slightly over winter months when electricity consumption is higher. This can be seen in **Appendix 7 Trial 1: Short Term Forecasts.** Used in conjunction with probabilistic forecasts (uncertainty estimates) for the respective substations (to better understand the volatility of electricity use), it is proposed to provide short term forecasts that are suitable for assessing the best operating regime for network supporting technology such as energy storage devices. A number of substation and feeder specific forecast energy profiles will be loaded into the NME and power flow and nodal analysis studies will be run. Some studies will be focussed on the locations where energy storage devices have been deployed to assess the overall benefit to the network. Further development of probability forecasts has shown that the accuracy of such forecasts is strongly related to the mean daily usage of the substation for which the forecast is being carried out. This has practical implications for where monitoring may be necessary and the requirement for accurate information about the substation. It has also been found that accurate, efficient forecasts are possible using a smaller sample of the phases. This can be seen in **Appendix 8 Probability Forecasts Update**.

The development of medium term forecasts, although established for commercial customer loads, requires further development and refinement that can only take place when end point data is available for a longer period (more than two year's worth). To date volume quantities of data are only available for approximately 18 months so no medium term forecast energy profiles have been created for loading into the NME. When available, and loaded into the NME, it would be expected that these forecasts will allow the locations on the network that are seen to be outside of limits in terms of capacity or voltage to be assessed such that targeted solutions (eg use of demand response, energy storage or localised reinforcement, possibly by load balancing) can be recognised and planned.

The development of long term forecasts is primarily about applying one or more scenarios regarding the uptake of low carbon technologies in possible random or clustered allocations. This remains work in progress to the end of the project, but as for previous forecasts, the output will be a portfolio of load profiles to be loaded into the NME for assessment on the network. In this case it is not desired to establish the detailed impact on a particular substation or feeder, but rather to enable a system wide view to be obtained regarding the overall impact. Different scenarios may have different impacts; ultimately the decision as to which scenario is the correct one is a subjective choice, but the confidence attached to the forecast that is linked to a scenario is crucial to the subsequent investment decisions. To some extent the selection of one scenario over another is fairly arbitrary as no one scenario is likely to be a complete vision of the future. Rather, the underlying purpose of such analysis is to identify strategies which can successfully adjust to meet a range of futures by observing the common aspects and key differences between each scenario.

Learning Points – Use of Modelling With Forecasts (Short, Medium and Long Term)		
No	**Topic**	**Learning**
1	Short Term Modelling	When the forecasting algorithm(s) are complete, it would be expected that energy profiles can be generated and loaded into the NME to assess the preferred operating regime for network technologies such as energy storage.
2	Medium Term Modelling	When the forecasting algorithm(s) are complete, it would be expected that energy profiles can be generated and loaded into the NME to assess the preferred solution to individual network problems recognised at particular locations; possible solutions could include do-nothing, arrange demand response from customers, or plan a targeted reinforcement project (eg selectively balancing the load on the network).
3	Long Term Modelling	This is about modelling different scenarios of low carbon technology take up, either random or clustered. When the forecasts are used to establish which EV, PV or HP energy profiles to load against each customer, when loaded in the NME it would be expected to see the impact on the network. This is about informing the best strategy to meet a range of scenarios, rather than planning specific solutions to any local network problem.

2.6 Use of Modelling with Virtual Monitoring (Buddying)

The process of buddying is designed to create energy profiles that can be loaded into the NME based on a small population of known half hourly energy profiles. Given that very few customers are currently monitored (250 for the project), and that it is uncertain as to how many half hour profiles will be available to a DNO from smart meters in the future, the use of buddied profiles is fundamental to the use and accuracy of the NME.

The accuracy of buddying is currently being assessed by comparisons with substation monitoring (aggregating loads in the NME and assessing the difference between the calculated feeder load and the substation monitoring feeder loads). Consideration also needs to be given to network losses (unmetered loads such as street lighting). When refined, it is anticipated that the use of buddying and aggregation with reasonably available end point data can be used in the modelling environment to effectively assess the network, and to do so with only a minimal requirement for substation monitoring (on the basis that aggregated loads are known to correlate with substation loads). Similarly, in the absence of reasonable quantities of half hourly end point data, buddied load profiles can be validated by aggregation and comparison with substation monitoring.

Initial assessment of buddying and aggregation techniques have been described in **SDRC 9.5(c) Aggregation** and the refinement and scaling up of these techniques remains work in progress to the end of the project. The most recent analysis has revealed that:

- The accuracy of the buddying is related to the time interval over which the buddying is applied (eg 4 weeks is better than 1 week). In particular all buddying methods perform better than a simple benchmark.

- The buddying accuracy reduces but not significantly over the entire trial period. This means it is not necessary to re-buddy too regularly. This is valuable to the DNO.

- The accuracy of the buddy is closely related to the number of customers on a phase and, slightly less so, to the mean daily demand on the phase. In particular this may help to indicate where monitoring or buddying is more appropriate for a given feeder.

- The accuracy of the buddy is highly seasonal. Less accuracy is observed for winter periods as opposed to summer periods. This is likely to be due to the increased variability of loading at such time periods.

- Methods must be developed for modelling commercial properties; when not accounted for accurately they have a disproportionate impact on the overall buddying accuracy.

This can be seen in **Appendix 9 Buddying Progress Report.**

Learning Points – Use of Modelling with Virtual Monitoring (Buddying)		
No	**Topic**	**Learning**
1	Loading energy profiles into the NME	The NME requires all end points to have a load profile assigned if the studies carried out are to be meaningful. Actual half hourly energy profiles are not currently available in large quantities and an alternative technique is required to create profiles for use in the NME. This can be achieved by buddying known customer profiles to all other end points.
2	Reducing the need for substation monitoring	If confidence can be gained from buddied profiles by comparing aggregated profiles (established in the NME) with load profiles measured with substation monitoring, then the need for actual substation monitoring may be reduced as the aggregated values become virtual monitor values.
3	Reducing the need for end point monitoring	If aggregated buddied load profiles compare well with substation monitoring, then the allocation of buddies can be regarded as successful and less actual end point data is required for the analysis of the network in the NME. This could be useful in the scenario where only aggregated end point data is available to a DNO from smart meters.

3 Use of Modelling to Support Others

3.1 Customers

The NME is a tool for DNOs to view and model the power flows and voltage drops on all parts of the network. As customers take up low carbon technologies such as electric vehicles, photo voltaic or heat pump technology, the demands on the network will grow and the ability of a DNO to manage the network in changing circumstances is crucial to support customers. As discussed in previous sections, the NME allows a DNO to model particular future scenarios, plan targeted solutions to specific network issues and to manage technology already connected to the network (eg energy storage devices). All customers benefit from these aspects indirectly in the sense that this both facilitates the choices being made by customers (to adopt the technologies), and also to experience the minimum impact in the cost of operating the network as a result. By targeting solutions to specific problems, deferring works where possible, and recognising which works can be completely avoided, the total indirect benefit to customers also includes the construction works disturbance also avoided.

The main reason why customers contact a DNO (apart from loss of supply related matters) is to request new or modified service connections. The ability process such requests quickly and efficiently is key to supporting customers and the NME has a number of benefits compared with traditional methods for assessing new load. Firstly, the NME is preloaded with the network connectivity model of the network, the type of circuit components, and their characteristics. This means that the operator of the NME has only to add the new service and the load profile for the customer representing the new load. This is much quicker than building the connectivity model and assessing the loading contribution from other customers on the circuit, which is the traditional approach. Additionally, by using an energy profile in the assessment (rather than an ADMD value), when assessed in the NME the output allows a clear assessment; a large peak load may well be acceptable for the new load provided that the peak does not coincide with the peak loading pre-existing on the network from other customer. Conversely, a coincidence of peak loading should result in the application being assigned the reinforcement cost that would result if pursued, and this is clearly to the benefit of the existing customers already connected to the network.

Learning Points – Use of Modelling to Support Customers		
No	**Topic**	**Learning**
1	Indirect Benefits	The NME allows a DNO to facilitate connection of low carbon technologies by customers, minimise reinforcement costs and minimise the need for reinforcement works and consequential disruption.
2	Direct Benefits	The NME allows a DNO to respond faster and more efficiently to new connection requests for new services. Compared with traditional ADMD methodology, the use of energy profiles for this purpose ensures that acceptable loading of the network is accepted, and genuine overloading of the network is correctly assessed with reinforcement costs charged to the new connection to the benefit of existing customers.

3.2 Industry

Larger non-domestic customers are primarily interested in supply reliability and energy reduction as a means to achieving a reduction in their operating costs. The ability of a DNO to model its network accurately is key to planning investments in the low voltage network, and targeting investments to ensure that the network remains within prescribed limits. This allows the DNO to control its own costs and manage the network to optimise reliability for all customers.

The NME allows a DNO to assess specific feeders and substations to identify which ones are likely to experience significant peak loading, and where non-domestic customers with large electrical demand are connected to these circuits or substations, there is a possibility of solving the network issue by means of reducing demand via one or more of those customers. The customer may elect to support the DNO by reducing demand to an agreed programme or upon specific requests typically by reducing demand from air conditioning (allowing the temperature to rise) for a period. In this scenario the customer saves energy as well as potentially earning a fee for providing the service to the DNO. The DNO can optimise the timing of the demand response programme based on the load profile information calculated for the feeder or substation.

Learning outcomes regarding the application of demand response are discussed in **SDRC 9.8(a) Parts 2 Demand Side Response** and **Part 3 Network Controlled Demand Side Response and Energy Efficiency.**

Learning Points – Use of Modelling to Support Industry		
No	**Topic**	**Learning**
1	Indirect Benefits	The NME allows a DNO to facilitate the operation of the network reliably and within limits at least cost, allowing the overall charge to customers to be minimised.
2	Direct Benefits	The NME allows non-domestic customers connected to the network to be targeted for demand reduction, based on their location on the network, and the timing of the demand reduction required to best suit the network. The customers involved benefit from a reduction in energy costs and may receive a fee from the DNO for the network support provided.

3.3 Local Government

Local government has an important role to play in helping to meet UK energy and climate change policies. They are typically responsible for large estates, and they can contribute by reducing their own carbon emissions. They can also encourage and enable reductions by residents, businesses and visitors by supporting deployment of renewable energy technology in a locally appropriate way. An example of this may include the provision of public electric vehicle charging facilities; such choices are more likely to encourage residents that commute to work or shop locally by car are more likely to feel at ease when deciding to purchase an electric vehicle. The reverse may also apply (lack of public facilities discourages take up electric vehicles).

Local authorities also influence commercial developers, property developers and large scale social landlords (eg Bracknell Forest Homes), and each of these correspondingly interface with DNOs to request new connections or for additional capacity. It follows that there may be some advantage in bringing these parties together for a two way exchange of information. In one direction, the local authority and developers can inform the DNO of locations of likely development and technology choices and policies being considered, and this can be used by the DNO to influence the choice of forecast profiles to be loaded into the modelling environment. Depending on the study being run, and the confidence assigned to the data, this may allow the DNO to assess the overall investment required in the network to support local prospective local developments. In the other direction, the DNO could share some aspects of the output of some forecast studies (eg in the form of red, amber or green network on a map background); this could allow the local authority to understand the effect of technology take up on the network in terms of prospective construction works; this can be used to inform residents and maintain the best relationship between local authority, DNO and resident at times of frustration caused by the disruption. Similarly, developers may benefit for understanding choices that they can make to minimise the connection costs they incur by choosing developments where the network has more existing capacity to support the development.

To better understand the relationships between these parties, a stakeholder workshop was held. Scenarios in a number of aspects were discussed, and the prospective benefits assessed. The scenarios chosen were:

1) Network capacity availability becomes increasingly uncertain with rapid low carbon transition
2) Increasing number and range of low carbon technologies
3) Rapid dispersion of low carbon technology impacts electricity network
4) Housing association is due to refurbish part of its existing housing stock
5) Commercial business model used by developer is constrained by DNO licence requirements with regard to reserving network capacity several years ahead.
6) Growing need to understand availability of network capacity as low carbon transition accelerates.
7) Time lag on relevant training due to rapidly evolving low carbon transition
8) Increasingly dynamic nature of network increases the need for reinforcement
9) BFC approves new housing development and accompanying sustainability statement.

Following the discussions it was recommended that scenarios 1), 3) and 4) would justify some further consideration, particularly between the DNO and the local authority. Scenarios 2), 8) and 9) were judged to justify no routine engagement, and scenarios 5), 6) and 7) may justify some interactions.

The scenarios, solutions risks and investment returns, together with the conclusions are discussed in detail in **Appendix 10 Town Planning Report.** Of these SSEPD will consider:

Scenario 1: **Network capacity availability becomes increasingly uncertain with rapid low carbon transition**
Smaller developers may benefit from an LV network map of the Bracknell Forest area with a 'traffic light' indicator assigned for the level of network load. This resource could also include links to relevant connection guidance and contact details to facilitate engagement with potential connection customers (i.e. those who are unfamiliar with the process). Developers who are familiar with the process can learn to interpret the traffic light indicator in terms of the impact on connection costs and reflect this in the choices that they make, and in advising their clients regarding costs.

Scenario 4: **Housing association is due to refurbish part of its existing**

housing stock

Housing associations are under pressure to maintain their housing stock to a good standard with particular regard to energy usage. Some solutions such as increasing thermal insulation have a beneficial outcome to tenants, the housing association and the DNO; other solutions such as large scale deployment of PV technology (eg solar panels on the roofs of block of flats) could result in significant problems on the low voltage network.

SSEPD's network modelling can be used to inform the housing association. Regular engagement between SSEPD and the housing association to share information on upcoming refurbishments and the evolving impact of low carbon technologies will ensure that the DNO can manage the network effectively, either by influencing the housing association regarding technology choices (eg combining thermal storage with PV) or by including network reinforcement in programme of works to the best interest of customers, housing association and DNO.

Learning Points – Use of Modelling to Local Government		
No	**Topic**	**Learning**
1	Availability of Network Capacity	The local authority will gain little benefit from direct access to the Network Modelling Environment or the "traffic light" status indications that come from it; however, smaller developers may be able to use this type of output to make more informed choices about where to make new connection requests or the implications regarding costs for the applications that they do make.
2	Refurbishment of Housing Stock by Housing Association	Local authority housing associations are likely to apply low carbon technologies (eg solar PV) to their housing stock in a relatively large and concentrated scale; this is likely to have an impact on the low voltage network. An ongoing engagement between the DNO and the housing association will allow the DNO to influence the choices made by the housing association based on the studies obtained from the network modelling environment. In reverse, it is a forum for the housing association to inform the DNO of the planned programme of works for the housing stock, allowing the DNO to incorporate revised load profiles into the modelling environment; this will allow the DNO to improve the accuracy of the modelling studies which will inform its own programme of works.

4 Conclusions

4.1 DNO Investment Decisions

The NME has been demonstrated to correctly calculate the electrical loading and voltage drop on the low voltage network, based on the energy profiles with which it is loaded. The advantage of the NME compared to traditional modelling and power flow analysis tools is that it already holds the network data (connectivity, circuit and equipment types, and their characteristics) and that the calculations carried out are based on the half hour energy profiles assigned to each end point. In other words, it does not require a model of the existing network to be built or loaded prior to the running of individual studies, and there is no requirement to make, or rely on, assumptions regarding the diversity of energy usage (as is the case with traditional ADMD based modelling).

To achieve these advantages does require that the NME is fully loaded with valid data in advance of being used, and that the network data is then kept up to date. The source GIS data has been captured in line with historic and current regulations (eg the need to advise on the geospatial location of cables), but there is less certainty about connectivity. For use in a modelling environment particular concerns have been recognised in aspects of the recorded data including uncertainty as to which main a particular customer is connected to when multiple mains are present, type of cable where incorrectly recorded at time of installation, electrical phase connectivity of customer service cables, and the linking of customer addresses to the network. Gaps or errors in these aspects clearly compromise the calculations being carried out. In each case the issue has been considered in detail and assumptions have been made; in the case of linking customers to the network, this has been assessed on an individual circuit basis and resolved prior to running studies. Where assumptions have been made about electrical phase allocation, it is considered that the results of studies are to be regarded as sufficiently accurate to give confidence in aspects of overall assessment (e.g. number of affected circuits, extent of the overload or voltage problem, general location along the circuit, etc.). It would clearly be inappropriate to suggest that the precise level of actual unbalance between electrical phases on a circuit can be assessed meaningfully if the phase connectivity has been assumed. This is an area where further analysis remains to be carried out, ie to compare power flow and voltage drop studies on circuits where the phase allocation is known and applied with the same studies carried out using assumed allocation criteria.

The output of the NME studies are presented both numerically and graphically using a red, amber and green colouring of nodes and sections of circuits to allow the user to visualise the scale and location of the problem (if any). Adding a new service and running a study is possible as a means to allow new connection requests to be assessed, and this has benefits of speed of calculation and relevance of outcome in that proper consideration is given to the peak loading, so that new loads that don't take the circuit outside of current and voltage limits are accepted, and those that do are correctly charged for the consequential reinforcement.

Further, using this approach, and by the application of forecast energy profiles for some customers projected to have adopted low carbon technologies such as electric vehicles, the NME can be used to identify the areas of the network caused to exceed limits. This can be used to inform the DNO where investment in the network is required, taking account of the context of the forecast. A specific study looking at the take up of electric vehicles revealed that by 2022, using DECC Scenario 3 for EV uptake, feeder circuits will be vulnerable to overloading, particularly on the sections of cable nearest to the substations, and in the periods of spring and summer. Substations with fewer customers connected may have more headroom per customer and appear to be less vulnerable to overloading. The nodal voltages on the circuits analysed were observed to remain with in limits for the scenario assessed.

The effective running of the NME depends upon it being loaded with relevant energy profiles. These could be provided by Energy Suppliers having obtained them from smart meters. This will not be available for all customers for several years, and even then other factors such as data protection and cost may limit the availability of half hourly data for direct use by a DNO. Hence other techniques to generate relevant end point profiles may be particularly valuable. Buddying of customers to other customers where their energy profiles are known is one such technique, and this is currently being assessed in the project. When confidence is gained in the technique this may provide an effective form of virtual monitoring, and by allowing meaningful studies to be run in the NME, the total quantity of substation monitoring and end point monitoring can be minimised.

Forecasting algorithms are also being assessed in the project; these will allow energy profiles to be assigned to customer endpoint relating to short, medium and long term scenarios, allowing their impact on the network to be assessed. It is too early to comment on the network impact, but increased use of the NME is growing confidence that when the forecasts are refined, meaning full studies can be run and the outputs used to inform short term operational decisions as well as medium and long term investment decisions.

4.2 Others

Both domestic and non-domestic customers will benefit from improved modelling being carried out by a DNO. The fact that reinforcement by targeting locations on the network actually most needing reinforcement, or confidence gained that reinforcement can be deferred for a period, will allow costs and disruption can be minimised.

There are direct benefits from the NME to domestic customers when applications are made for new connections; these can be assessed quickly and accurately, allowing an assessment of loading that will permit direct connection if possible, and connect with network reinforcement where necessary; in this scenario the reinforcement costs can be correctly charged to the new connection without penalty to existing customers.

In some locations on the network where load or voltage are found to be outside of limits, where a non domestic customer is connected to the network at a relevant location, the DNO will benefit if that customer can reduce demand at times of the network peak. Such a demand reduction can provide a direct benefit to the non-domestic customer in terms of reduced overall energy demand and consequential cost saving. Additionally, participation in such an arrangement on an automated or programmed basis could earn the customer a fee.

Local authorities and associated community housing associations can also benefit from the use of the NME, but this is linked more to enhanced engagement between the parties and sharing of information; in this way the interests of the DNO and wider community can be better understood and choices made to encourage adoption of low carbon technology where this can be supported by the network.

5 Transfer to Business as Usual

5.1 DNO Investment Decisions

The NME is being used in a large number of studies within the project, and the analysis of techniques of buddying and forecasting remain the subject of trials to the end of the project. These techniques are key to the assignment of relevant network end point load data in the NME; meaningful operation of the NME for business as usual will be considered when confidence is gained in these techniques.

A significant pre-requisite for the operation of the NME is that it is loaded with "sufficiently correct" network data; the project will inform the definition of "sufficiently correct", but once this is understood the adoption of the NME will require potentially large volumes of data cleansing type activities. These may include:

5.1.1 Connection of service cable to main cable – the majority of service cables have not historically been recorded in detail at the time of installation, and they have been "automatically" assigned to the nearest main cable at the time of establishing the NME. For the majority of service cables, this is logical and correct as there is only one mains cable in reasonable proximity. This can however be confused in a number of situations (eg near to a substation where mains cables converge, or in streets where two or more mains cables run in the same footway or carriageway). In some cases it is "obvious" to an informed operator which is the correct assignment, and many situations can be corrected with reasonable confidence following manual inspection. Others service cables require some other technique applied on site to establish connectivity. The questions to answer for large scale use are:

- How many are there?
- How would they be corrected (and at what cost)?
- Is it sufficient to know "which service cables are of uncertain connection" and reflect this in the output of any study carried out in the NME?

5.1.2 Type of cable(or conductor) – The majority of mains cables are of known type and this is correctly recorded in the existing GIS system; for those that are not known, for the project, a methodology was derived for applying an assumed type of cable. It is practically impossible to prove whether the assumptions are correct, but the application of an assumption is crucial to operation of the NME. The methodology is subject to review, but can be applied in a semi automated manner if the NME was to be built for the whole SSEPD network. The same applies to service cables, except that the quantity is much larger, but the choices available are less (every "unknown" service cable can be assumed to be "35sqmm aluminium concentric"). In this case the questions to answer for large scale use are:

- How many are there?
- Are the assumptions to be made going to lead (on average) to optimistic or pessimistic outcomes? (eg if the assumed cable size chosen is small compared to its actual size, the assumed cable type will have less capacity than the actual cable)
- Does the operator of the NME need full visibility of which cable sections have assumed characteristics?

This issue is relatively easy to manage when scaling up, but some choices need to be made.

5.1.3 Single phase service cable electrical phase allocation - very few service cables have a known electrical phase allocation recorded in the GIS or SIMS databases. For the project, this has been overcome by applying an allocation methodology (RYBBYR…). It is proposed to study further whether this should be biased in some way (eg to match the ratio of MDI readings at the substation), or whether the actual phase allocations to be identified for all customers. What ever the outcome of this assessment, a scaled up deployment of the NME will require all customers to allocated in some way and it is better that this is done optimally once at initial data migration. The questions are:

- Which methodology should be applied (in the absence of known phase allocation)?
- How much would it cost to assess the actual phase allocation for all customers? (and could this be an opportunity to engage directly with all customers?)

The unbalanced loading of the LV network is generally well recognised, and it is anticipated that when the electrical studies are run in greater scale, it may be shown that improving load balance (eg by means of power electronics, traditional balancers, or by physically reconnecting some customers) may offer an effective means of increasing the headroom of the circuit without resorting to full scale reinforcement (eg overlaying whole cables). Hence the focus on appropriate allocation of service cables to electrical phases as shown in the NME.

5.1.4 Matching of address points to the electrical network – the correct function of the NME requires that every customer (represented by their MPAN number) can be correctly assigned to an address point (Ordnance Survey provide Address Layer 2) which is represented on the map background and linked to the network. This matching has been closely tracked for studies run within the project, as un-matched addresses will result in the load from that unmatched customer not being included in the study; this would be expected to result in an optimistic outcome from the study. This was recognised in the earliest stages of the development of the NME data migration, and work carried out to optimise the address matching criteria (maximum matching success with a minimum of false positive matches). Over 80% of addresses in the project area were matched successfully as a result of this approach. For the remaining unmatched addresses (over 3400), they are being manually fixed on demand where required for the project. For a scaled up deployment, this matching exercise needs to be carried out completely prior to the migration of data into the NME. The questions to answer are:

- How would unmatched addresses be matched most efficiently?
- Could some areas be left unmatched by accepting that the NME would be usable (for power flow and voltage analysis) in areas with full matching only? (eg address matching is known to be low in some commercial areas where businesses operate out of “units” on privately owned estates)

If the NME is to be built and regarded as the centre of correct network information for other purposes (apart from power flow analysis) then this may also justify additional effort to resolve the address matching issues. In particular, the migration of the connectivity data to the Distribution Management System (DMS) is the primary reason to pursue this.

The importance of linking customer addresses to the correct location on the network has already been recognised within SSEPD, primarily to assist with the correct reporting of customer outage information and to improve the response to customers in the management of faults. For this reason, the Mapping Services Department is establishing a team whose role it is to carry out this matching using data within existing databases, but using the learning from the project regarding the optimal process. When complete, this will provide immediate benefit to SSEPD and will facilitate the scaled up adoption of the NME.

A number of electrical planners (and Desk Top Quoters (DTQs)) have already been locally introduced to the NME as an alternative tool for establishing the feasibility of accepting new connections onto the network. They recognise the advantages and are keen that the NME be adopted for business as usual. While this is a great endorsement of the NME, the real benefit can only be realised after significant work to prepare the network data as described above.

For the network wide assessment of the performance of the network, for current loading, and for short medium and long term forecasts, a more fundamental change is required to the business approach, moving from being reactive (fixing network problems when they have occurred) to being proactive by running the large scale study and trusting the result to make actual decisions to support the short, medium and long term requirements of the network. This is not about the NME alone (as a tool), but also about the buddying, aggregation and forecasting methodologies being assessed to the end of the project.

5.2 Others

DNOs (and local authorities) are already charged with improving their engagement with their stakeholders, and there is a desire that discussions should grow and achieve better value for all parties. The analysis carried out revealed that sharing of a network diagram colour coded to reflect the headroom on the network can help these discussions with a local authority and would be very informative for smaller developers. Following adoption of the NME, it is easy to envisage the use this modelling information in this way.

Similarly it was identified that local authority housing associations would jointly benefit with the DNO by engaging to share information on refurbishments and the impact of the low carbon technologies that they plan to incorporate. An innovative solution (eg combining PV installation with thermal storage) will have a lower impact on the low voltage network, reduce the energy costs of the tenants, and reduce the risk to the housing association of unexpected costs from the DNO. This joint interest is likely to incentivise the discussion, but there may be a need for one party to take a more leading role.

6 Appendices

The following appendices are available upon request – please contact futurenetworks@sse.com

Appendix 1	**The Network Modelling Environment**
Appendix 2	**Network Statistics**
Appendix 3	**Improving Network Modelling Techniques Using Profiles**
Appendix 4	**Results of Increased Loading Studies**
Appendix 5	**Typical Power Flow Analysis – Load Multiplier 2x**
Appendix 6	**Typical Nodal Analysis – Load Multiplier 2x**
Appendix 7	**Short Term Forecasting report**
Appendix 8	**Probability Forecasts Update**
Appendix 9	**Buddying Progress report**
Appendix 10	**Town Planning Report**

Scottish & Southern
Electricity Networks