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DEVELOPING FUTURE POWER NETWORKS

SDRC 3 - SIM Hotspot Analysis
Hotspot Map Update

LCN Fund Low Carbon Networks · ALSTOM · Aston University Birmingham · University of BATH · CGI · CISCO · Cranfield University

1. Executive Summary

11kV Networks in FALCON's trial area in Milton Keynes have been analysed to determine the current flows and voltages under normal running and n-1 conditions. This analysis identifies hotspots, the points on the network with least thermal and voltage headroom. The first version of this analysis was carried out using a modified version of the 11kV nodal analysis tool GROND, with estimates for distribution substation loads for each half hour, type of day and season being created to reflect the Elexon profiles.

This update of the analysis uses the components of the SIM as a means of validating that they can work together to produce credible results. These components are;

1. The FALCON Energy Model, used to create load estimates
2. IPSA, the network modeling tool at the heart of the FALCON's SIM, and
3. The Authorised Network Model (ANM), which extracts and transforms data from several Western Power Distribution systems, to create the data for nodes, branches and connectivity for use by IPSA.

IPSA was able to process data from the ANM and the Energy Model to carry out the analysis demonstrating the technical compatibility of the various inputs and outputs. The results of the analysis were in general consistent with expectations showing that there are no voltage or thermal constraints on the network under normal running configuration, no voltage constraints under n-1 conditions and only a couple of feeders indicating potential thermal constraints under n-1 conditions.

The updated analysis also confirmed the benefit of analysing networks on a half hourly basis using different season and day types. Temporal variations are seen in the affected the section of network identified as having least headroom and the normal open point which would be the best selection.

The updated analysis mostly identifies hotspot feeders that are different to the initial results, though one feeder was identified with low voltage headroom in both sets of analysis. There was, however, consistency with the previous analysis in terms of average maximum loadings and the frequency distribution curves of the results. The voltage drops under n-1 conditions are a little larger in the revised analysis but are still within the expected range.

These results are sufficient to conclude that the components of the SIM are working well together and will generate credible results. The only caveat to this conclusion is that the Energy Model, while working well for feeders that are dominated by domestic load, tends to overestimate loads on feeders dominated by industrial or commercial (I&C) customers. Where this was evident, by comparing the Energy Model estimates with representative values from SCADA, then the results were excluded from the analysis as they would inevitably show a greater degree of thermal overload than is actually the case.

Improving the output of the Energy Model is a high priority to maximize the quality of the SIM output. Previous work has succeeded in improving domestic customers estimates and there is ample reference data from the substation monitoring in South Wales to support similar forensic analysis of the industrial and commercial estimates as a prelude to using the FALCON monitoring data for further refinement.

2. Introduction

This document, the Hotspot Map Update, describes the work undertaken and results found when reproducing the Hotspot analysis first carried out in November 2012. This analysis covers the six primary substations in Milton Keynes that are at the core of the FALCON trials area. This work forms part of FALCON's SDRC 3 with the purpose of providing an early check that the tools that support the SIM give usable results.

References

1. 2012 Hotspot Analysis Report: Hotspot Map - Initial Report v0.3 10-12-12.
2. Initial Load Estimation Report: Load Data Findings (Logica Work) - Initial Report 1.1 26-04-13.docx
3. FALCON SIM Architectural Design Document (ADD).

Background to the SIM

As the revised Hotspot analysis is a test of the SIM at an early development stage, it is useful to understand the nature of the SIM to provide context to the analysis that has been carried out. The SIM is a large and complex software development being undertaken as a major workstream of the FALCON Project in order to model the network response to different load scenarios in the future. The SIM requires an accurate and complete network model (termed the Authorised Network Model or ANM), appropriate LOAD profiles for each substation in the model and other ancillary data such as cost model elements and certain weather and soil characteristic data (for underground cables).

Using this input data, the SIM can execute power flow analyses for the network (ANM) under different load scenarios and can extend this analysis for several decades into the future as the network and load evolves. Where load growth results in network overloads at certain points as the through time simulation proceeds, the SIM can propose network "fixes" based on the application of a number of "Intervention Techniques" corresponding to actual remediation methods being trialled on the real-world FALCON network. The SIM can follow these through, searching the solution space for viable forward strategies that result in usable networks throughout the period of the simulation. Optimum strategies are based on cost data and effectiveness of the interventions.

The simulation search space is extremely large and the SIM is optimised to carry out the analysis efficiently. It is readily seen that the SIM is a particularly complex piece of software.

The SIM itself has two main software components:

- A network modelling tool (NMT) based on the commercial software package available from TNEI called IPSA. Core IPSA has many commercial users and is being enhanced as a product by TNEI using the FALCON project as a vehicle for development. IPSA is thus the power flow analysis core of the SIM;

- An enveloping high level wrapper layer called the SIM harness (SIMH) which renders the higher functions of the FALCON SIM available to the users. The SIM harness effectively implements the multi-year extended analysis capability of the SIM, the extended result browsing capability and other functions beyond the usual capabilities of the IPSA core network modelling tool element.

The overall High Level Design of the SIM is described in the SIM ADD [Ref 3].

Background to the Original Hotspot Analysis

This is an update to the work to create that first Hotspot map which used estimates of half hourly load at distribution substations for different seasons to examine the headroom on the network when considering voltage and thermal issues. The tool that was used for this network analysis was GROND which had been modified to allow the processing of multiple half hourly values rather than a single set of load values. The analysis was carried out for the Milton Keynes Network which hosts project FALCON. The original analysis confirmed that there is value in carrying out analysis on a half hourly basis over a wide range of seasons and types of day. It also showed that the network was free of thermal and voltage issues under normal conditions and highlighted those feeders with the least headroom under n-1 conditions.

3. Hotspot Map Update – Differences in Inputs

The updated Hotspot map analysis differs from the original version in the several ways, most significantly

1. The analysis tool used;
2. The network model, including the cable ratings used;
3. The load estimates;

The updated analysis therefore gives us an opportunity to update our understanding of the HV feeders with least headroom using the technology, data and processes that will underpin the SIM. These are still under development and so final SIM versions may produce different results, however the purpose of the analysis is to ensure that these components can work together and to glean new insights from the results that are produced.

The Network Analysis Tool

IPSA has been selected as the network modelling tool for the SIM. This will form the analytical core of the SIM that will be used to determine whether networks are compliant and represent the operation of the new techniques to resolve voltage and thermal issues. IPSA has some similarities with GROND in that they both represent the network as a nodal model in which substations, switchgear and joints on the network are modelled as nodes and the overhead lines and cables between them are modelled as branches. The voltages and currents at any point on the system are calculated using the principles of Ohm's and Kirchoff's laws. The systems may differ in underlying assumptions, for example GROND assumes that the three HV phases are balanced. Similarly there will be underlying assumptions about transformer tap positions that are not part of the data model that underlies GROND. These differences could have a minor impact on the results but are expected to be the least significant cause of difference between the original and updated Hotspot analysis.

The Network Model

In the initial analysis the representation of the network in GROND was already somewhat dated and not an entirely accurate representation of the network at November 2012. GROND was previously updated via a process to export network data from the Smallworld GIS model and convert the data to an appropriate format. This process was carried out infrequently with updates at intervals between six months and a year. At the time formulating the SDRCs the integration of WPD and Central network was underway. Later, the GROND update process was suspended following the decision to discontinue both Smallworld GIS and support for GROND. This was not a barrier to creating the initial Hotspot map but will have an impact on the differences that are seen between the two versions. The revised Hotspot map analysis uses FALCON's Authorised Network Model constructed from data extracted from the underlying systems in August 2013. This will reflect updates to the network from works that have altered the network itself such as new connections, asset replacement and fault repairs. Additionally there may have been minor changes to the way in which the network is represented following on from the transfer of data in the GIS system to EMU (the equivalent WPD application) and then through the new Extract-Transform-Load process used to generate the authorised network model. These might be minor changes such as a different number of decimal points in cable length measurements, or a slightly different set of defined cable types meaning that any cable types that are no longer supported will be represented as their nearest equivalent.
The previous Hotspot work found that analysis was sensitive to errors in the way that the network model was constructed. Changes to the underlying network model will have impacts that range from significant to negligible according the type and location of the change.

The Authorised Network Model is likely to be a better representation of the real network than the GROND model for the following reasons;

1) it is based on the latest information available from main data sources and so is as up to date as possible at the time of the hotspot analysis

2) the network model is more sophisticated with more information about each asset

3) the network model data is drawn from more than source, allowing for validation checks to be performed, and includes data taken from the control room system. Due to the safety critical role of control room systems there is less chance of connectivity errors affecting this data in comparison to a drawing system where connectivity errors may not be easily perceived.

As the two data models are in different formats it is not possible to easily determine the differences between them or to separate the differences that reflect a genuine change to the physical network from reclassification changes. However, feeders where the load estimates have remained relatively constant between iterations can give an indication of whether changes to the underlying network model have a significant impact on results.

The Load Estimates

The previous load estimates were created by replicating the functions of the Supplier Volume Allocation Agent used by Elexon as part of the settlement process. This is described in detail in the Initial Load Estimation Report [Reference 2]. This gave an estimate for the portion of the load at a distribution substation relating to non half hourly metered customers. Actual meter readings for half hourly metered customers were then added in as was an estimate to cover losses on the LV network and unmetered supplies.

The estimates used in the updated version of the Hotspot analysis are generated from the Energy Model under development by the Energy Savings Trust. Rather than using eight generic profile types, the Energy Model calculates the expected heating and hot water requirements for each property using details of the housing type, heating system and any energy efficiency improvements such as cavity wall or supplementary loft insulation. Other end uses, for example lighting, laundry, entertainment etc. are estimated using profiles that will reflect demographic data for the customers. For example the likelihood of a customer being in during the day will reflect their age and likely occupation. The Energy Model also covers industrial and commercial customers and reflects data such as the Standard Industry Classification code, floor area, number of employees etc.

For the original Hotspot analysis, load estimates were calculated for specific dates where temperatures were considered to be representative of the type of day to be modelled. The precise profile coefficients for those days were used in the calculations. In this iteration the estimates are generated using assumptions for temperature, wind speed and global irradiance that would be expected for different seasons.

The load estimates are expected to be a significant area of difference, and this is seen in comparative analysis given in the following pages. The increased sophistication of the Energy Model offers potential for more highly tailored profiles and therefore improved accuracy. However, at the same time, this improved accuracy is reliant on having good quality data, matched accurately for a large number of customers.

A major point of difference between the estimates used is the treatment of half hourly metered customers. The previous estimate incorporated the ***actual*** values that were metered and no estimation method could improve on these values which are by definition 100% accurate. However, the purpose of the Energy Model is to provide estimates that can;

1. reflect the changes expected in technologies installed, appliance efficiencies etc. and

2. understanding the proportions of the load by end use so that the potential for DSR can be assessed

This necessitates modelling, and therefore while the total annual load can be used for ensuring appropriate scaling, there will always be a reduction of accuracy in using a modelled estimate.

All estimation methods are likely to be able to predict the demand of a larger group of customers more accurately than they can any particular individual load as aggregation smooths out the impact of each individual customer's behaviour. Work on the LV Network Templates project has also found that estimates for substations that predominantly supply domestic customers are more accurate than those for I&C

customers where profiles for half hourly metered customers may not conform to the standard I&C profile shape.

There will always be a cut-off point where investing in increased model sophistication and data provision is not cost effective in terms of the incremental improvement to the model results. This was highlighted in the Initial Load Estimation Report with the example of a substation supplying a Rugby ground. The load profiles on different Saturdays were greatly affected by whether or not home games or training sessions were occurring, but the cost and difficulty of incorporating this level of information within the Energy model was unlikely to provide value for money. Prior to reaching this type of point of diminishing returns it is likely that incremental changes can improve quality. This has been seen in the LV Network Templates project where results were improved by making progressive changes across all the elements of normalisation, clustering, classification and scaling within the model.

Cable ratings

The assumptions for cable ratings may not be identical between the two iterations. In this update summer and winter ratings are used for underground cables calculated on a cyclic load basis. Previous ratings were calculated on a constant current basis.

Macro vs. micro level comparison

It is clear that each of the changes in inputs listed above will have an impact on the outputs. The analysis has not been designed to determine the impact of each factor individually by changing one variable while holding all the others constant. This is partly driven by the practicalities of creating the required experimental conditions. For example, it would be time consuming to create a revised network model in the GROND format and to create additional Elexon estimates for any new substations etc. Given that we do not expect to export from the Authorised Network Model to GROND in the future this development would be wasteful and would not alter the choice of network model for the SIM. The impact of changing from Elexon estimates to Energy Model estimates has been considered in the Findings section.

4. Analysis Scope and Methodology

Scope

The 2013 SDRC 3 network Hotspot derivation is a static one-off network analysis designed to match that carried out in 2012 on the same area of network. It will readily be seen that this is a very restricted form of network analysis compared to what the full SIM is actually designed to achieve. Thus, there is no requirement to extend the Hotspot analysis into the future, nor to propose remedial actions to be taken in response to the identified Hotspots themselves applying these and computing the costs. Indeed, the Hotspot analysis itself is a straightforward “one dimensional” network analysis particularly suited to the capabilities of the NMT core of the SIM, IPSA.

The Hotspot analysis is therefore carried out using a special build of the FALCON SIM parallel to the main SIM development. It takes IPSA in a cut down SIM wrapper and uses the specially prepared FALCON data

inputs (ANM, Load profiles) to provide a much more complete and accurate analysis than that carried out at the earlier project milestone in 2012.
Each of the 11kV Feeders associated with the core six primaries is analysed in turn. The core primaries are: Bletchley, Child's way, Fox Milne, Newton Road, Newport Pagnell and Marlborough Street. The analysis uses the Energy Model output table to populate the loadings at each substation on each 11kV feeder.
The analysis;

- considers thermal overload and voltage levels during normal running and under n-1 analysis;
- includes different standard day types and each of the 48 half hourly periods;
- only includes the current year;
- simplifies N-1 analysis to only consider the scenario where a fault occurs directly downstream of the feeder breaker. This simplification is continued from the original Hotspot analysis though within the SIM, IPSA n-1 analysis will be more rigorous analysing each network section in turn;
- does not carry out Fault level analysis, though this functionality will form part of the SIM.
- does not analyse CML, CI or Losses which will also be additional IPSA functionality for the SIM
- does not include suggesting investments to mitigate any network issues found;
- does not involve estimating the financial value associated with network attributes such as CML, CI or losses using cost models.

Results of the thermal and voltage analysis is recorded in a series of text files containing data for the network, day type, half hour period, running arrangements (normal / n-1) and load scenario the current, current rating and % rating, voltage and voltage change % for the most challenged sections of network. This should allow the feeders that are nearest to their limits for current or voltage to be identified.

Assessment Method

A large number of IPSA files were created that combined the nodal model information from the Authorised Network Model with the Load Estimates generated using the Energy Model. Additional files were created to represent the reconfigured network under n-1 conditions. The same simplifying assumptions were applied for n-1 analysis as had been used within GROND for the initial Hotspot Map. These are that the most onerous condition will be a network failure directly downstream of the source circuit breaker. This will result in the entire feeder requiring backfeeding from an alternative network. This is modelled by opening the circuit breaker, closing a normal open point and carrying out a network analysis of the reconfigured network. Where there is more than one normal open point then each possible configuration is assessed. In reality, if this were to result in overloading the combined circuit it would be possible to reconfigure the network further to share the burden of the faulted feeder among more than one “donor” circuit. Therefore this is a slightly pessimistic measure but one that is still useful and good for relative comparisons.

In selecting the feeders that have the least headroom the assumption is made that all the possible normal open points will be available for use and therefore the “best” results of the possible options will be used.

In assessing headroom, each element of the network will be different. The results reported will reflect the most extreme values seen on the network so typically the highest voltages will be seen near the primary or points of generation infeed, the lowest voltages at network extremities. The circuit with highest percentage of its rating may not always occur near the primary where loads are highest because ratings may not be constant at all parts of the network, reflecting the differences in overhead and underground construction and network tapering.

While estimates are created for the substations within the FALCON network area, there are some feeders that would be used as backfeeds that do not form part of the FALCON area that require load estimates to enable the power flow analysis under n-1 conditions. In the previous version of the Hotspot map the maximum load values for these substations were profiled using an average profile developed from the feeders that had SVAA estimates. For this version average profiles have been established using SCADA monitoring at the source breakers and the load has been prorated to the distribution substations. The difference in method is not expected to result in major changes to the results. Neither method will be replicated in the SIM which will have load estimates for every distribution substation.

Load Data Validation Checks

Before running the analysis it was important to check that the load data required was present and that it had been loaded in the correct units. So while the Energy Model output specifies Load in Watt, this was converted to kW before loading into IPSA.

Load data was validated in two ways.

1. Within IPSA

Using the scenario of one HV feeder backfeeding another allowed a check to be made that the two types of load estimate are consistent in scale. Checks were made by comparing the load on the donor feeder (the sum of both estimate types) and those seen just downstream of the normally open point that has been closed (just the Energy Model estimates). If the feeders are similar in composition a ratio of around 2:1 might be expected. A very high disparity in the scale of loading on the feeders might indicate an error in the data loaded into IPSA.

2.Comparison to average SCADA values

The Energy Model output was combined with connectivity data to allow aggregation of estimates by HV feeder, by season and day type. Once again this is not a precise check but simply a means of establishing that the results are of the right order. The results were seen to be of the right order, though with variations in quality, as discussed further below.

5. Findings

Load Data

The changes in the load data are considered first as this significant change in input will drive the changes in outputs.

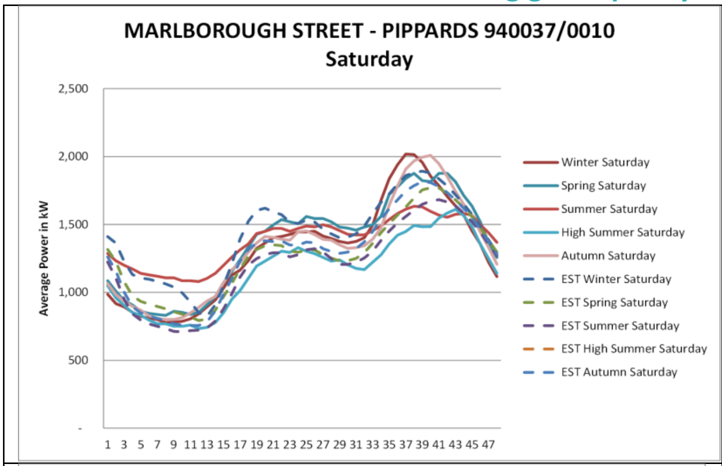
Data Quality

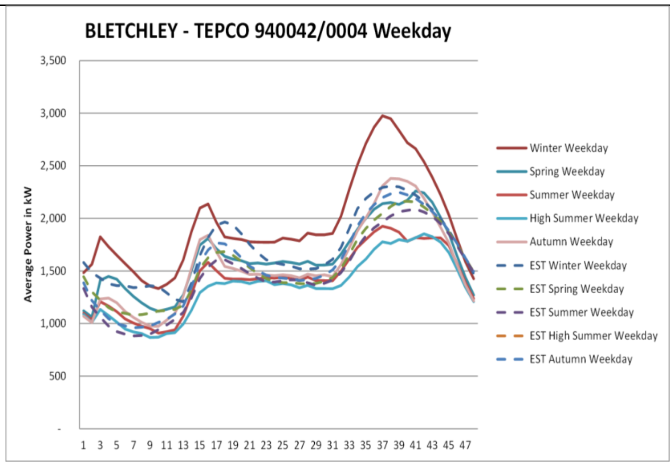
The compilation of the load estimates was hampered by being unable to provide an EAC for each non half hourly metered customer. The EAC values are extracted from the quarterly P222 files sent by data aggregators and this problem seems persistent across all DNO areas. Estimated EAC values have been used for some customers. For the vast majority of customers these have been based on the average of other customers within the same profile class and connected to the same distribution substation. This is better than using a global default value as it should reflect neighbours with similar housing types and heating systems. However in some cases, where a substation only supplies one or two industrial or commercial customers, then default values cannot be calculated in this way and a value must be determined another way, e.g. by considering other customers with that profile class on that HV feeder or for that primary. For larger customers this could introduce significant errors. Similarly not all customers associated with the network could be cross referenced in the other data sources needed for the data preparation stage of the Energy Model. Examples of this would be where a domestic customer that was shown within WPD records could not be matched to the HEED database or where an I&C customer within the WPD records could not be matched to Energy Model records to determine the type of business, building area, number of employees etc.

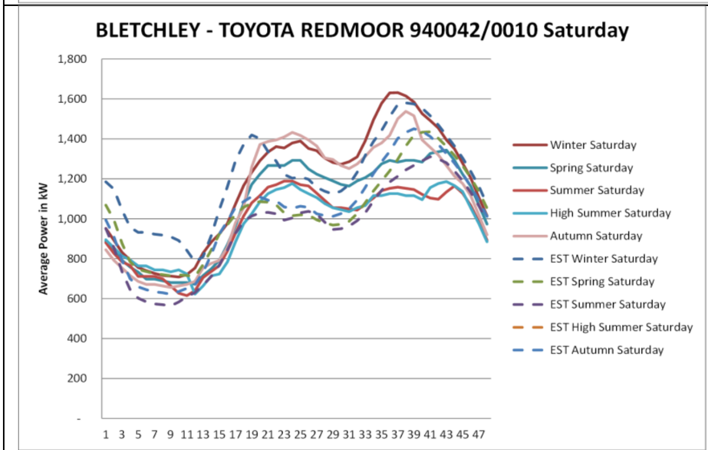
Comparison to SCADA values and Elexon Estimates

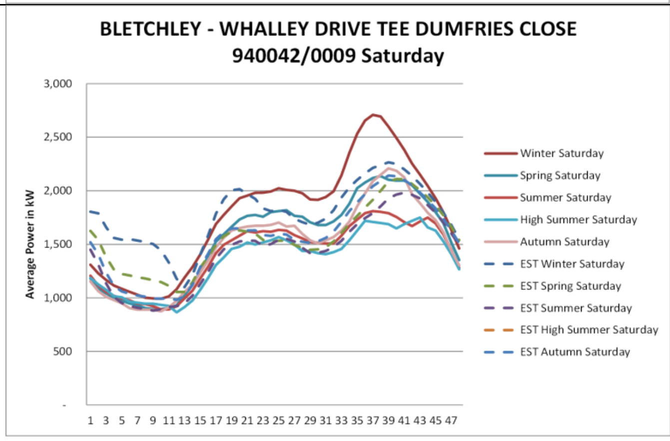
There is a good deal of agreement in the overall pattern and scale for feeders where load is dominated by domestic customers with load curves that reflect profile class 1. It can be seen that these good quality results are found on a variety of feeders across all of the primaries and for different day types.

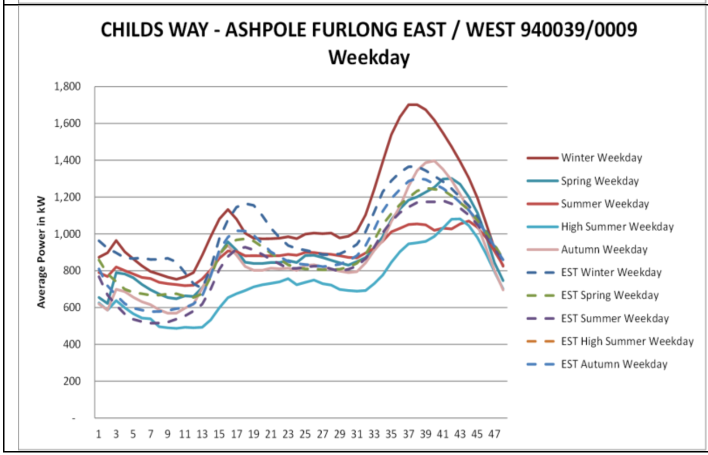
Domestic dominated feeders showing good quality estimates

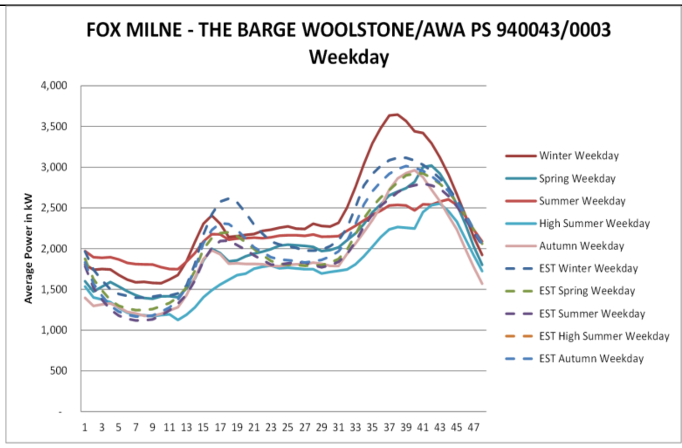


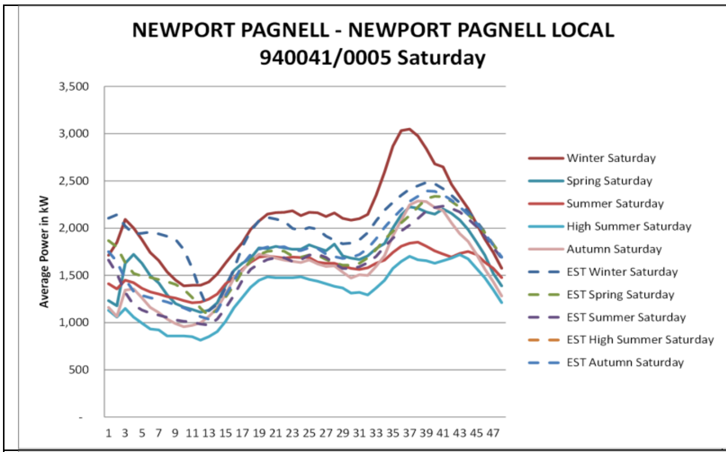


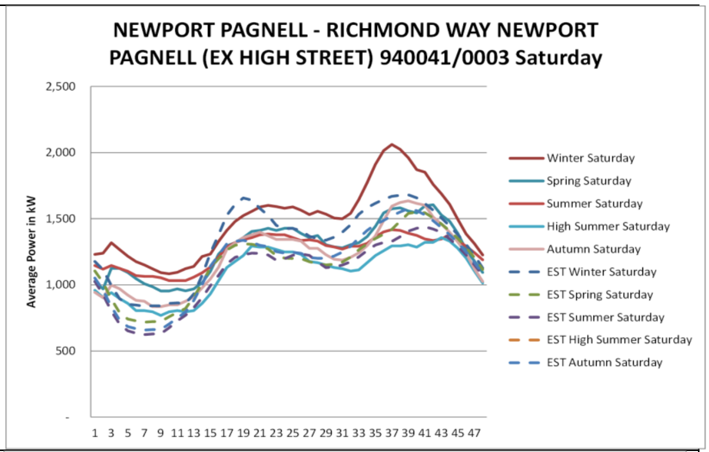


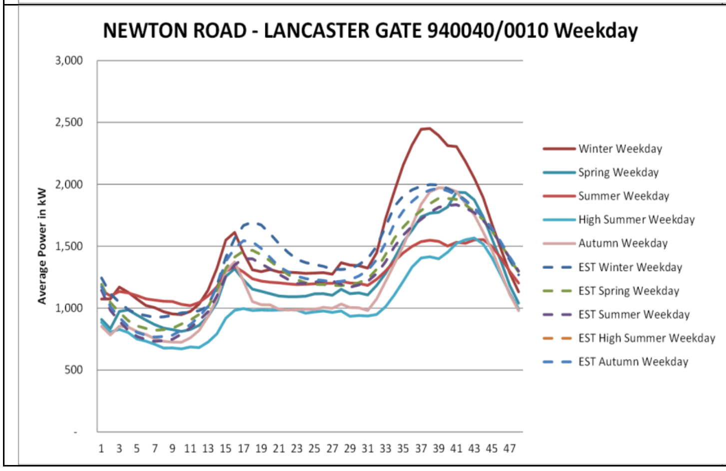


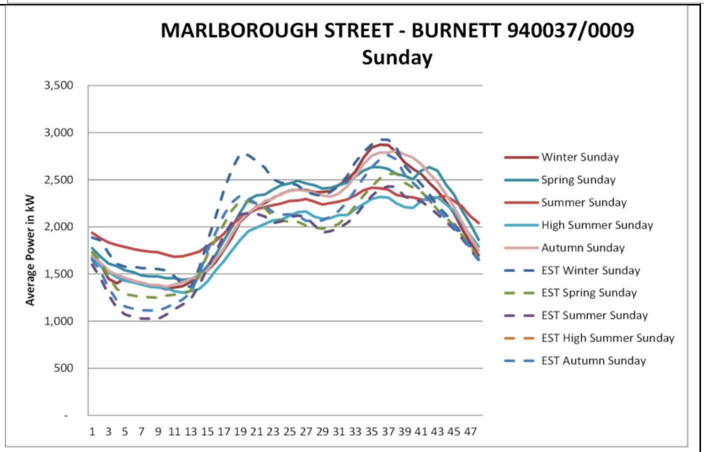








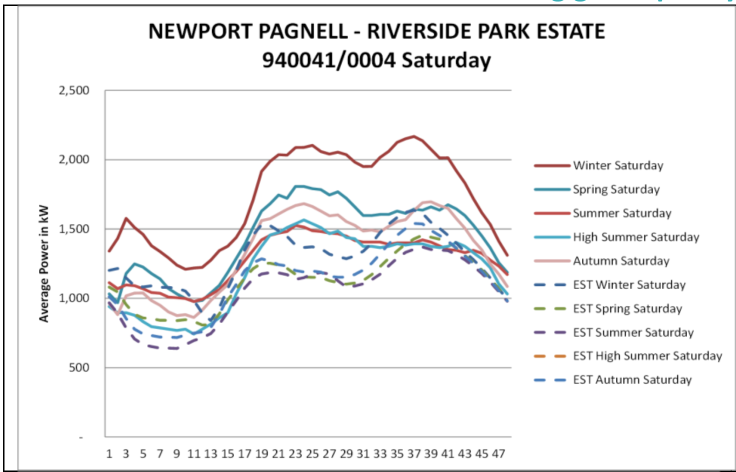


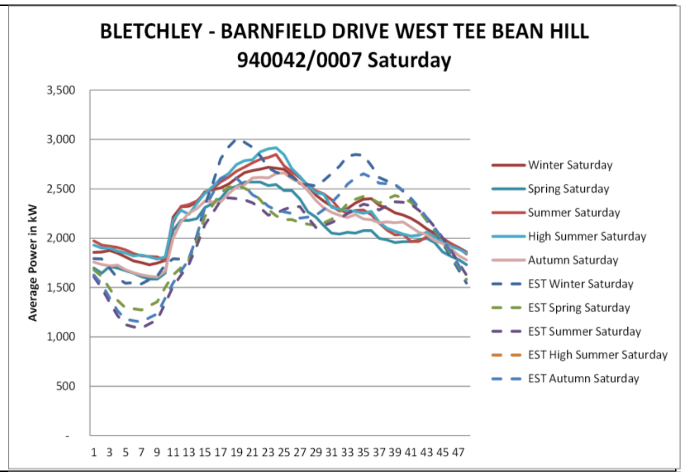


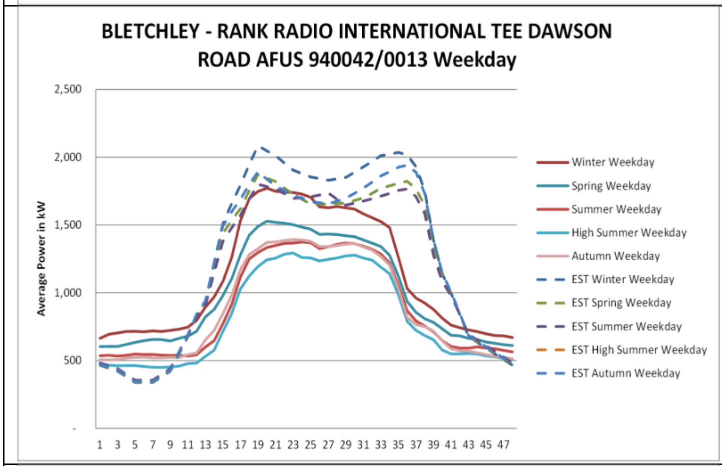
One common feature is that the estimates often understate the extent of the evening peak in Winter but are of the right order for other seasons. This suggests that the assumed temperatures within the Energy Model need revising however SCADA values for winters of other years should be used as a cross-check to ensure that weather variations for 2012 are representative. This should be fairly simple correction to apply and does not suggest issues with the underlying model.

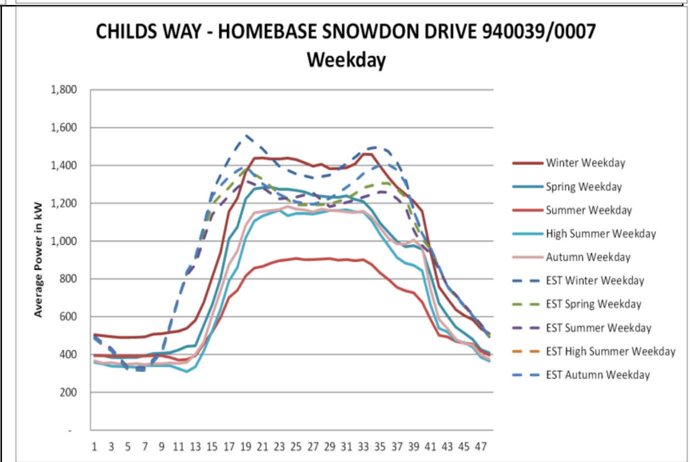
As well as the good fit for domestic dominated HV feeders there are good results for some feeders with mixed or I&C dominated loads.

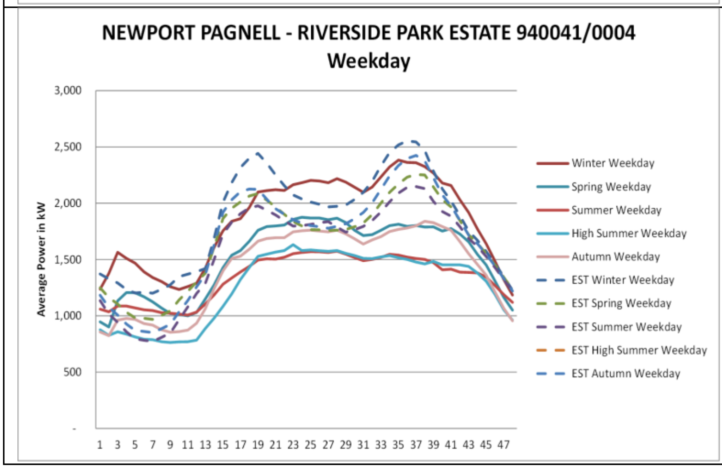
Non Domestic dominated feeders showing good quality estimates





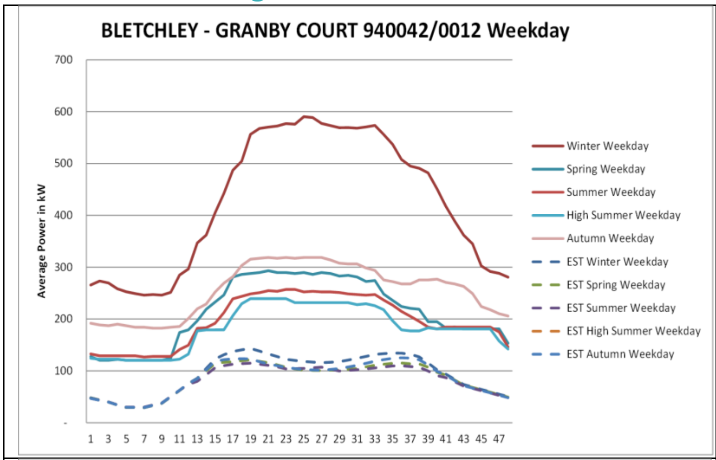


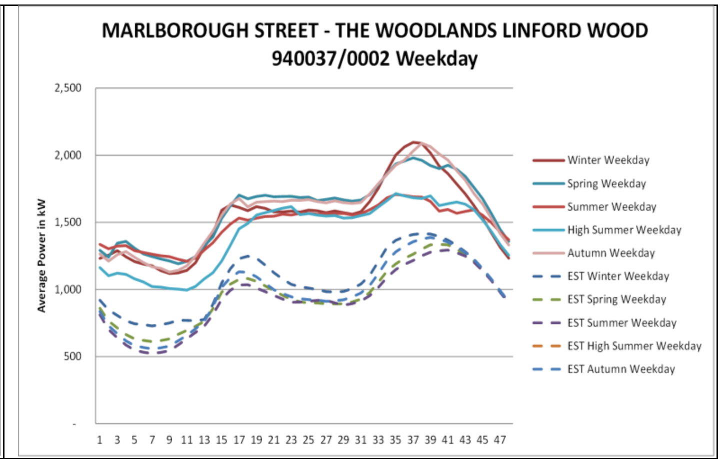


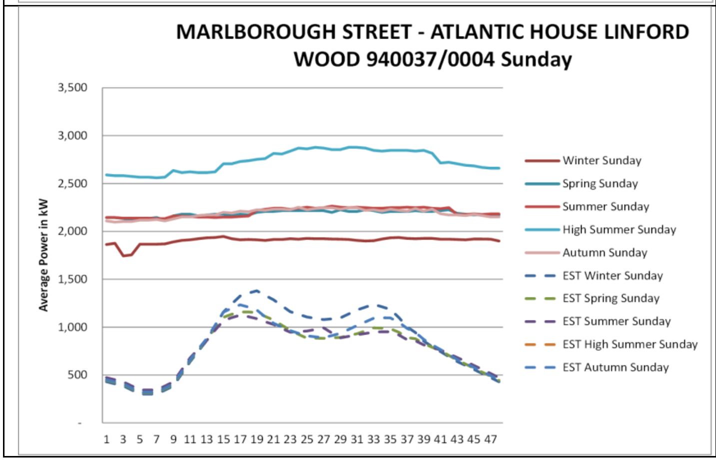


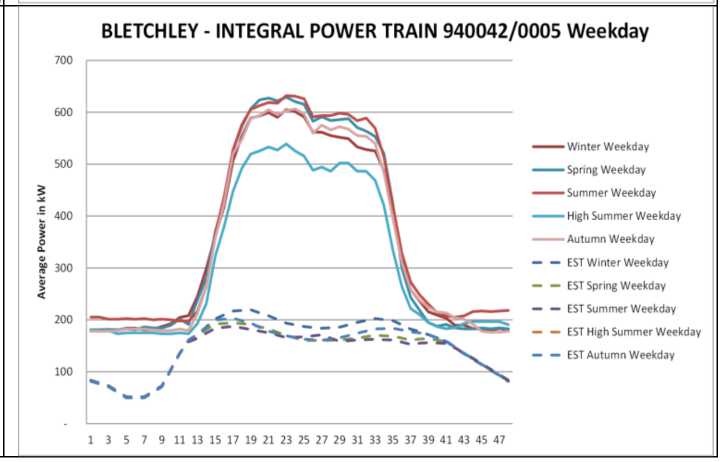
Sometimes the Energy Model underestimates the scale of the load. Given that it is more common to correctly estimate the scale for domestic feeders this suggests that a problem with the input data is more likely than a problem with the way in which the data is processed.

Estimates showing underestimation



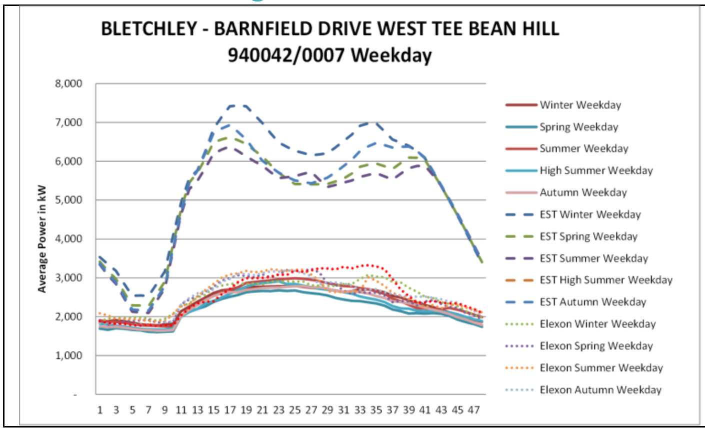


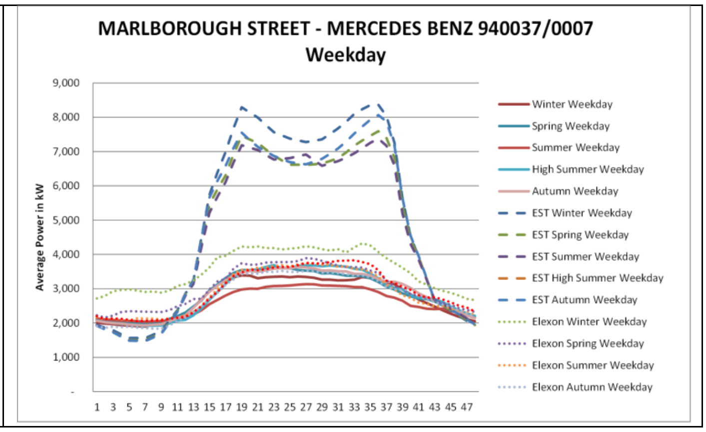


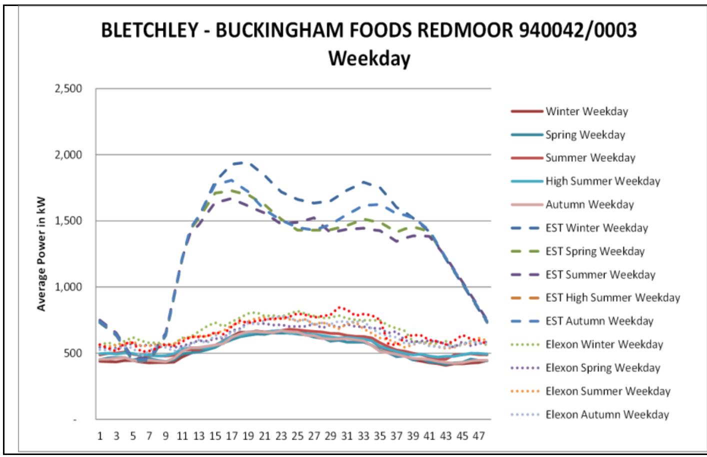


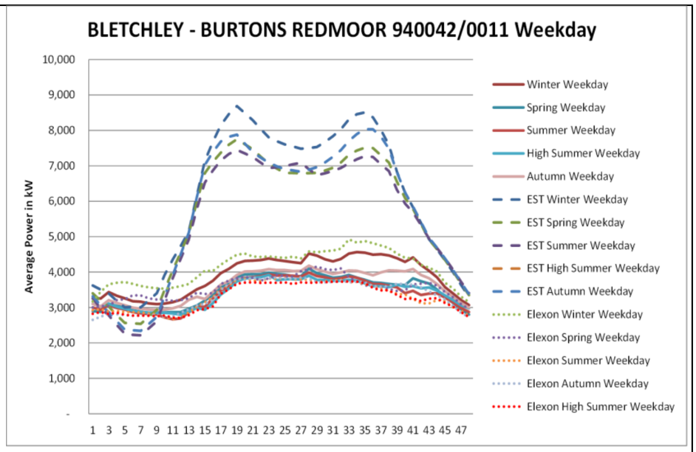
Overestimation occurs most frequently for I&C dominated feeders. This is the most common issue seen with the Energy Model output. Such levels of overestimation would greatly reduce the assessed network capacity within IPSA and would predict network issues where none exist. In the examples below the Elexon estimates have been added for comparison shown as dotted lines. It can be seen that in all the cases where the Energy Model is overestimating load, the Elexon estimates are very similar to the values measured by SCADA. Therefore the results for these feeders will be more accurate for the original Hotspot analysis than for the revised version.

Estimates showing overestimation





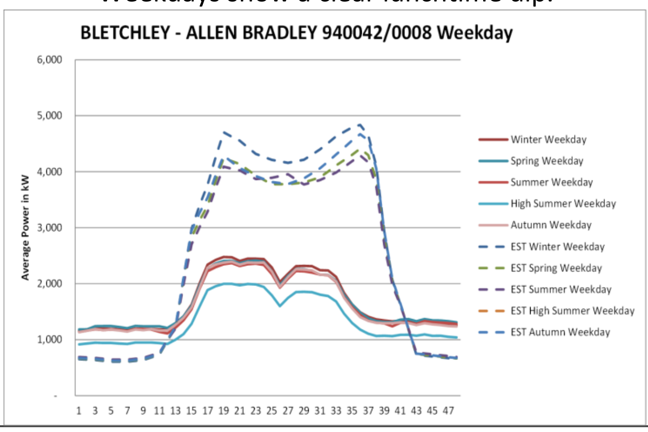




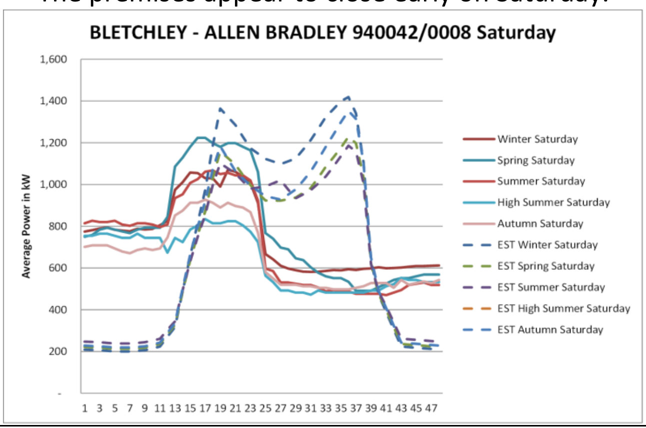
The Energy Model does not always reflect the impact that opening hours has on I&C loads.

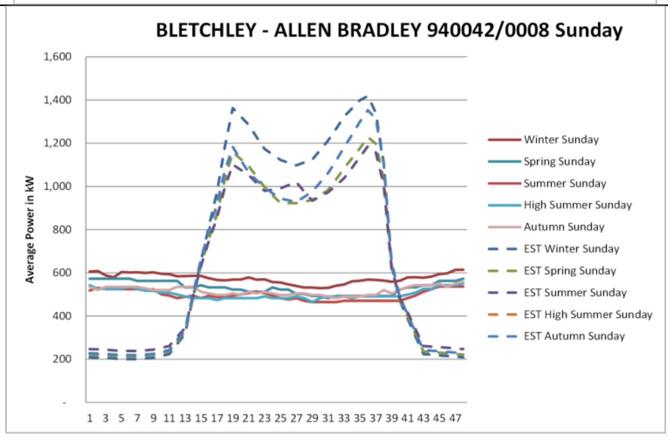
Estimates where I&C activity profiles require refinement

Weekdays show a clear lunchtime dip.



The premises appear to close early on Saturday.



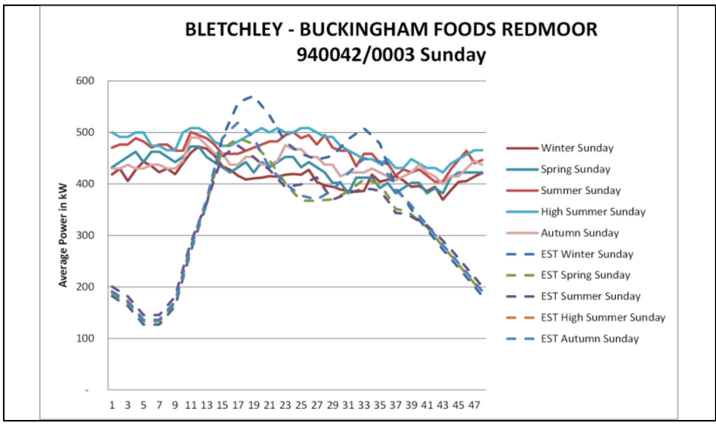


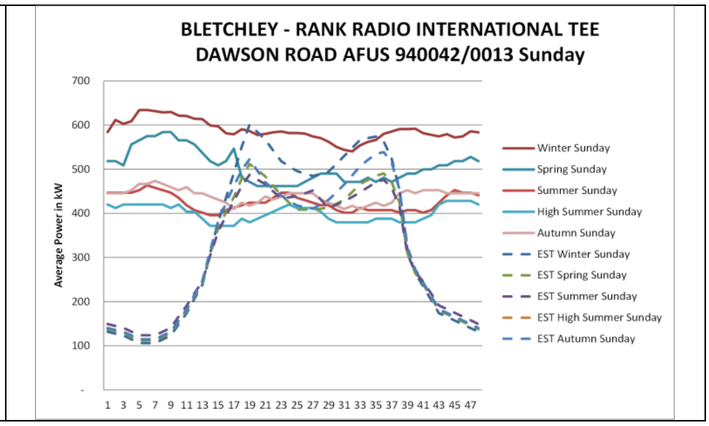
Sunday loading suggests that premises are closed.

Opening hours are the equivalent feature to whether a domestic property is occupied.

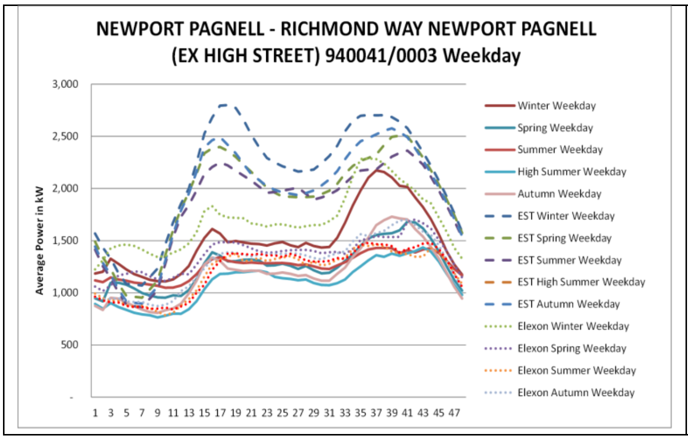
There is a need to be able to determine the likely pattern for I&C customers with greater accuracy than is currently supported in the model. This may require improved matching to business type, or additional sources of data to be included.

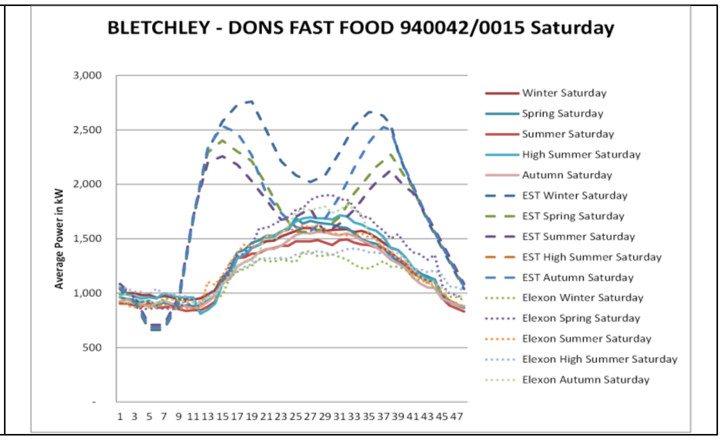
Two more feeders that do not reflect the actual Sunday load pattern are given below.



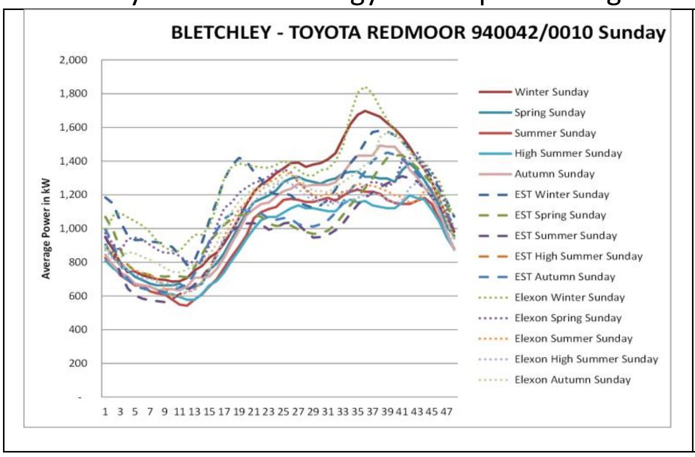


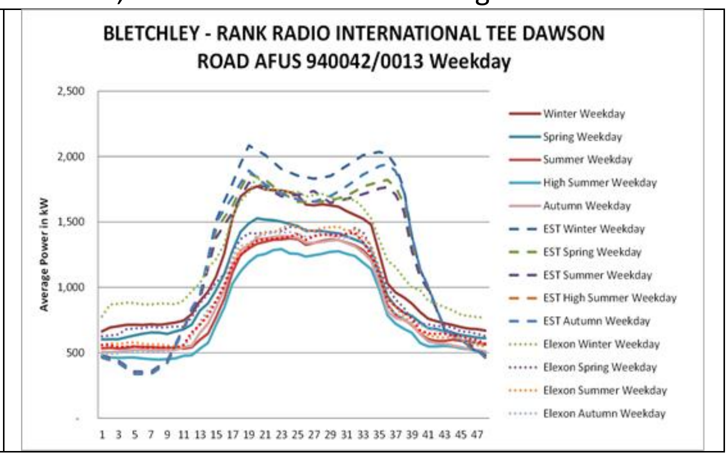
Very exceptionally the Energy Model shows issues with both the profile shape and peak scaling. Given that this is rare, this is also likely to reflect issues with the underlying data rather than the way in which the data is processed.





Generally where the Energy Model produces good estimates, the Elexon values are also good estimates.





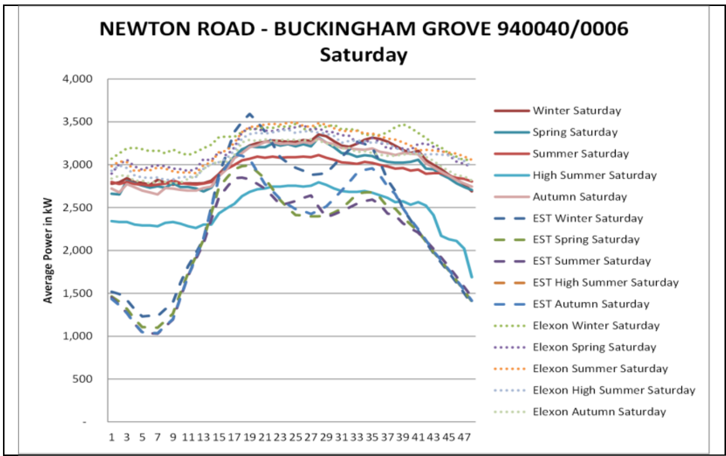
Headroom under normal running arrangements

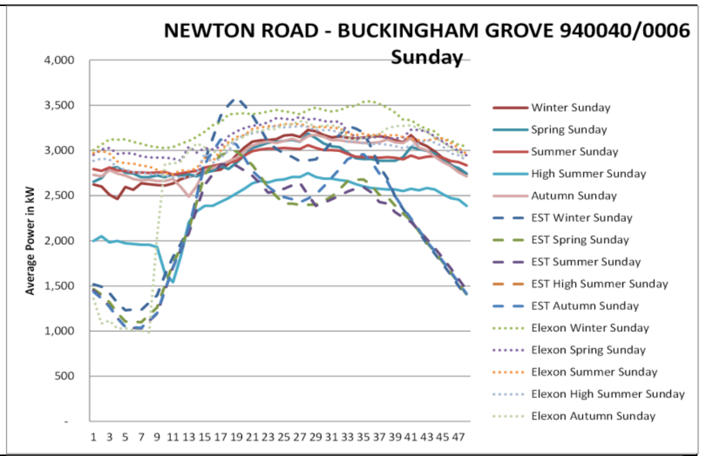
Thermal overload.

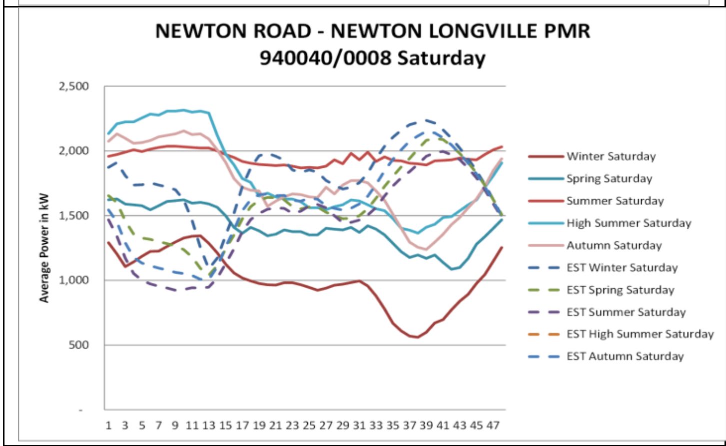
The impact of overestimation of load becomes instantly apparent in the voltage and load flow analysis of the network under normal running conditions. The following feeders are suggested to have high percentage loadings with the value reported representing the branch with least capacity. Some are reported as having exceeding their ratings, however it is clear that these feeders are those which are known to be overestimating load at certain times. For this reason the results where the load estimates were known to be overestimates were excluded from the rest of the analysis.

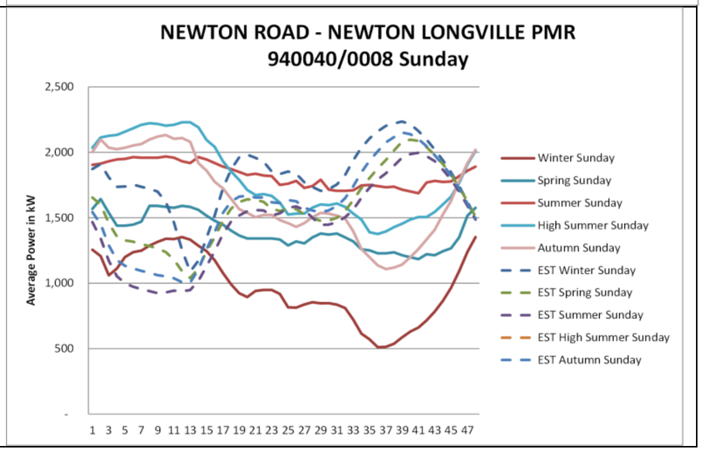
Feeder name	Primary number	FDR No.	Day	Highest % rating	Overall load curve	Quality
NEWTON ROAD - BUCKINGHAM GROVE	41P0019	6	Weekday	230%	I&C	Overestimate weekdays only
BLETCHLEY - IKEA STORE BLETCHLEY	41P0004	16	Weekday	192%	I&C	Overestimate weekdays only
NEWTON ROAD - ST DAVID'S ROAD	41P0019	7	Weekday	161%	Relatively Flat	Overestimate weekdays only
MARLBOROUGH STREET - CHESTNUTS	41P0034	8	Weekday	147%	Other	Overestimate weekdays only
NEWPORT PAGNELL - HOWARD WAY INTERCHANGE PARK TEE CRAWLEY ROAD	41P0020	10	Weekday	114%	Relatively Flat	Overestimate weekdays only
BLETCHLEY - BURTONS REDMOOR	41P0004	11	Weekday	98%	I&C	Overestimate
MARLBOROUGH STREET - MERCEDES BENZ	41P0034	7	Weekday	94%	I&C	Overestimate
BLETCHLEY - ALLEN BRADLEY	41P0004	8	Weekday	92%	I&C	Overestimate
BLETCHLEY - BURTONS REDMOOR	41P0004	11	Sunday	88%	I&C	Overestimate
BLETCHLEY - BURTONS REDMOOR	41P0004	11	Saturday	88%	I&C	Overestimate
NEWPORT PAGNELL - ALEXANDRA DRIVE	41P0020	7	Weekday	85%	I&C	Overestimate
BLETCHLEY - BARNFIELD DRIVE WEST TEE BEAN HILL	41P0004	7	Weekday	83%	I&C	Overestimate weekdays only
MARLBOROUGH STREET - BURNETT	41P0034	9	Weekday	75%	Domestic	Overestimate weekdays only
FOX MILNE - NORTHFIELD DRIVE WAYSIDE GROUP	41P0040	8	Weekday	75%	Relatively Flat	Overestimate weekdays only
NEWTON ROAD - BUCKINGHAM GROVE	41P0019	6	Sunday	71%	I&C	Overestimate weekdays only
NEWTON ROAD - BUCKINGHAM GROVE	41P0019	6	Saturday	71%	I&C	Overestimate weekdays only
CHILDS WAY - CBX4 TEMPORARY SUPPLY	41P0035	10	Weekday	67%	I&C	Overestimate weekdays only
NEWTON ROAD - NEWTON LONGVILLE PMR	41P0019	8	Weekday	66%	Other	Overestimate weekdays only
MARLBOROUGH STREET - ATLANTIC HOUSE LINFORD WOOD	41P0034	4	Weekday	66%	Other	Overestimate weekdays under w/e
NEWTON ROAD - NEWTON LONGVILLE PMR	41P0019	8	Sunday	58%	Other	Overestimate weekdays only
NEWTON ROAD - NEWTON LONGVILLE PMR	41P0019	8	Saturday	58%	Other	Overestimate weekdays only
NEWTON ROAD - CRAIGMORE AVENUE	41P0019	3	Weekday	57%	I&C	Overestimate weekdays only
NEWPORT PAGNELL - RICHMOND WAY NEWPORT PAGNELL (EX HIGH STREET)	41P0020	3	Weekday	53%	Other	Overestimate weekdays only
FOX MILNE - PINEHAM RIVER GAUGING STATION	41P0040	7	Weekday	53%	Relatively Flat	OK weekdays underestimates w/e

The only unexpected results relate to feeders from Newton Road which are not seen to be overestimating loads on the days where high percentage loadings are being registered.









Buckingham Grove		
Season	Saturday	Sunday
Autumn	63%	63%
Spring	59%	59%
Summer	57%	57%
Winter	71%	71%

For Buckingham Grove feeder the most overloaded branch is very consistent throughout the year.
G71855673 to 41D0337_BB01. This is rated for 4.76MVA at 11kV

Newton Longville PMR		
Season	Saturday	Sunday
Autumn	58%	58%
Spring	57%	57%
Summer	54%	54%
Winter	48%	48%

For Newton Longville PRM feeder the most overloaded branch is also very consistent
ALIAS-7649052-e to ALIAS-7850827-e, rated at 2.57MVA at 11kV

Both of these branches have relatively low ratings, suggesting that there may be an error in the underlying network model.

Where the estimates are low in comparison to the SCADA valued then these feeders have the lowest percentage rating results. Where load estimate quality is not expected to affect the results, the loadings range from 13% to 50% with an average of 29% loading which is in line with expectations.

Voltage

None of the feeders showed high voltages with the maximum value being 1.04 per unit, reflecting the choice of tap position rather than voltage rises due to connected generation.

Even with some loads being overestimated, none of the feeders showed low voltages beyond the normal range. The lowest values were seen on Bletchley - Burtons Redmoor feeder, where the estimates of load are exaggerated, resulting in a normal running maximum voltage drop of 4.2%.

The maximum voltage drop reported against feeders where there the estimates are good quality is 3.6% but average values are far lower than that at around 1.4%. Once again these results are in line with expectations. A similar frequency distribution pattern is seen to the initial hotspot map of a few instances of high values tailing off quickly to a large number of feeders with results around the average.

Voltage calculations are far less sensitive to error in the load estimates than the values for thermal overload and so are less likely to be useful for error checking.

Headroom under n-1 conditions

Thermal overload

The original analysis found that under the simplest test of single switching the networks are largely able to restore supplies without experiencing thermal constraints. There appeared to be one feeder, Bletchley feeder 07 Bean Hill Neapland where the load on restoration from either of the normal open points would exceed 100% of rating for at least one section of the feeder. However, in reality load could be shared more widely by performing more than one switching operation. This feeder also showed high levels of loading (above 60% rating) under normal conditions.

The original analysis identified the following feeders were identified as having the least thermal headroom under n-1 conditions.

Circuits with least thermal headroom previously	
BLETCHLEY	>>07 BEAN HILL NEAPLAND
FOX MILNE	>>08 NORTHFIELD DRIVE WAYSIDE
BLETCHLEY	>>11 BURTONS REDMOOR
NEWPORT PAGNELL	>>07 ALEXANDRA DRIVE NEWPORT

These feeders continue to have high calculated loading but the picture is made uncertain where overestimates for certain substations will impact the assessment under n-1 conditions.

In the original analysis the Child's way -04 Leisure Plaza Feeder was previously identified as a hotspot due to an error in the underlying network model. In the updated analysis the estimates for that feeder appear low.

For the feeders where overestimated load is not likely to affect the results, the most highly loaded feeders are as follows. The two feeders from Newport Pagnell show instances where the maximum loading is over 100% on winter weekdays of 123% and 115% respectively. In the case of Newport Pagnell Local the overloading extends to several half hour periods but for Riverside Park Estate there are only a handful of half hour periods around the evening peak where the 100% rating is exceeded.

Most highly loaded feeders – Revised Analysis		
NEWPORT PAGNELL - NEWPORT PAGNELL LOCAL	41P0020	5
NEWPORT PAGNELL - RIVERSIDE PARK ESTATE	41P0020	4
NEWTON ROAD - BUCKINGHAM GROVE	41P0019	6
NEWTON ROAD - NEWTON LONGVILLE PMR	41P0019	8

The feeders at Newton Road are expected to feature as hotspots, given their low apparent headroom under normal conditions.

Average n-1 loading

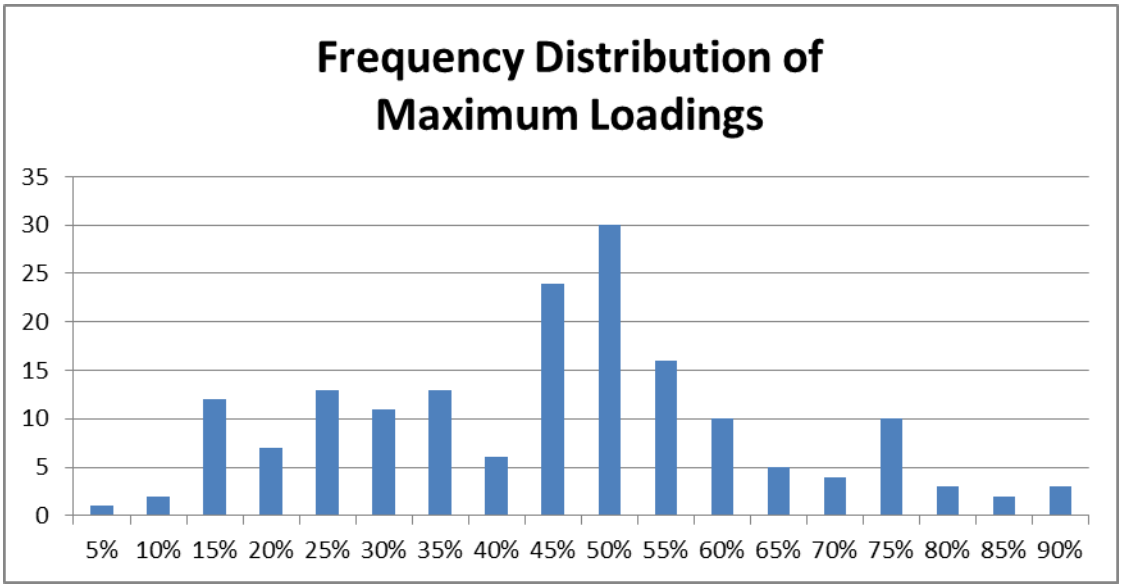
In the original analysis it was found that the overall average maximum loading of feeders under a single switching resupply is very much lower for the whole FALCON area at around 38%.

The revised analysis suggests that for feeders where overestimation is not suspected this value is now 35%. Given that the feeders that have been excluded from this calculation are those that previously had higher loadings then this result is likely to have been skewed to a lower value due to that exclusion. Therefore the overall picture is consistent between the two sets of analysis.

Frequency distribution of maximum loading

In the chart below maximum loadings are calculated assuming the best normal open point is used for each half hour period, then determining the worst loading for each season and day for each feeder.

The frequency distribution chart is consistent with previous findings that there is an approximate normal distribution with the majority of maximum loadings between 25% and 75%.



Voltage

The following feeders were identified as having the least voltage headroom under n-1 conditions in the original Hotspot map. There were no examples of voltage limits being breached.

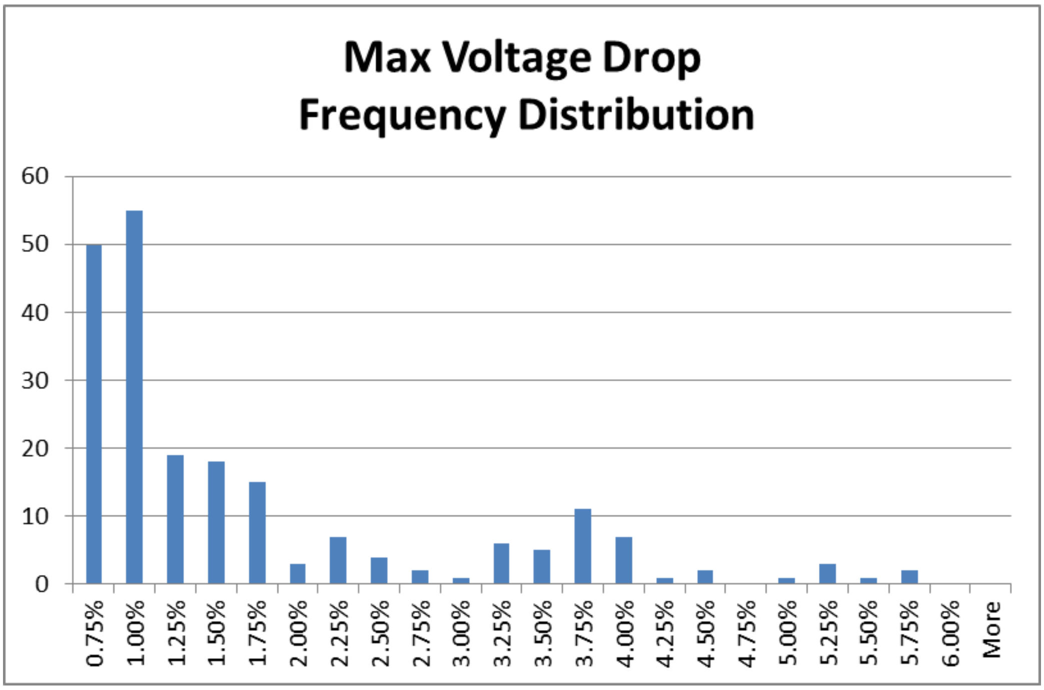
Feeders with least voltage headroom - initial hotspot analysis	
NEWTON ROAD	>>08 SELBOURNE AVENUE MILTON
NEWTON ROAD	>>05 SHOULDER OF MUTTON BUCKI
BLETCHLEY	>>11 BURTONS REDMOOR
MARLBOROUGH STREET	>>02 THE WOODLANDS LINFORD WO

In the revised hotspot analysis, filtering out results impacted by overestimates, the voltage limits are not breached either with the worst voltage drop given the best choice of normal open point being 5.58%
One of the previously identified feeders with the worst voltage, Newton Road - Shoulder of Mutton feeder, is also in the revised top feeders.

Feeders with least voltage headroom – Revised Analysis		
NEWTON ROAD - NEWTON LONGVILLE PMR	41P0019	8
NEWPORT PAGNELL - NEWPORT PAGNELL LOCAL	41P0020	5
NEWTON ROAD - SHOULDER OF MUTTON	41P0019	5
BLETCHLEY - TOYOTA REDMOOR	41P0004	10

Previously the frequency distribution of results showed a rapid tail off around the values for headroom and voltage with no result above the 4.25% bracket. Rather than there being a significant number of circuits with similar values, the feeders identified with least headroom were more like outliers that were not representative of the general network.

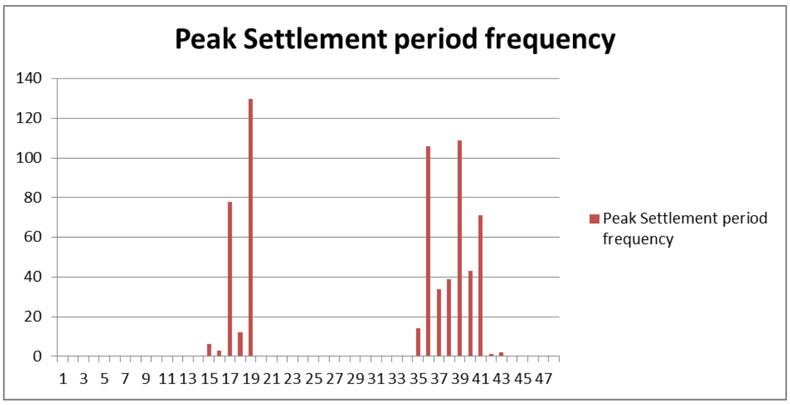
The updated analysis results, seen in the chart below, shows a less rapid tail off with more instances of higher voltage drops as well as a higher maximum voltage drop value.



Temporal Variations.

The original Hotspot analysis found that there was value in extending the network analysis beyond the use of a single set of load values representing the expected winter peak. It found that some HV feeders showed considerable loading during the Summer and that peak times were different for neighbouring feeders providing some confidence that there would be situations where automatic load transfer would provide benefit.

The chart below shows the frequency in which each settlement period was that in which the maximum loading occurred on a feeder for the sample of feeders and day types provided by the Energy Model.



It can be seen that while the evening peak is still the dominant pattern there are many cases where the peak occurs in the morning confirming the results of the initial analysis. The Energy Model estimates for HV feeders dominated by industrial and commercial load are seen to tend peak during the day rather than in the evening.

In addition to the potential for automatic load transfer, with no feeders experiencing peaks in the early afternoon or overnight there is considerable scope for shifting demand to these times.

In agreement with earlier findings, industrial and commercial feeders continue to experience high loadings on summer weekdays which, while lower than winter days are still far higher than the weekend loadings.

Impact of season and daily variations on results

The impact of the variations over time of the distribution substation load estimates can be seen in the IPSA results for the most highly loaded branch within the n-1 result files. As well as recording the level of loading, the IPSA result file identifies that branch which has the highest percentage loading.

The table below shows that for the same feeder restored from the same normal open point, the changes in loading on both feeders over time results in the worst affected branch changing. Over the course of the year the worst affected branch moves between six different points on the network. Sometimes this is quite brief as in the branch 41D6284_RM01 to G71681679 which is only the most highly loaded branch for two half hour periods within the year and G71681679 to 41D5850_RM01 which is only the most highly loaded branch for one half hour period. This reinforces the need to check for overloads on a half hourly basis and that the approach of modelling load at each distribution substation, rather than pro-rating loads at the primary substation down the feeder, will result in a better understanding of the actual load flows.

Worst affected branch count of half hours.				
Worst affected branch	**Season**	**Saturday**	**Sunday**	**Weekday**
41D0375_BB02 to 41D5678_RM01	Autumn			9
41D5678_RM01 to G71681555	Autumn			10
41D5850_RM01 to 41D0375_BB01	Autumn	37	33	
41D6284_RM01 to G71681679	Autumn			2
G71681679 to 41D5850_RM01	Autumn			1
G71688507 to 41D6284_RM01	Autumn	11	15	26
41D5850_RM01 to 41D0375_BB01	Spring	38	35	28
G71688507 to 41D6284_RM01	Spring	10	13	20
41D5850_RM01 to 41D0375_BB01	Summer	42	43	36
G71688507 to 41D6284_RM01	Summer	6	5	12
41D5850_RM01 to 41D0375_BB01	Winter	37	31	30
G71688507 to 41D6284_RM01	Winter	11	17	18
The results above apply when feeder 41P0004 – 13 is switched out and restored from 41P0004-16 via the NOP connecting nodes 41D0375_BB01 to 41D0375_CB01				

Another similar impact of considering the particular load flows at this level of detail is that it can be seen that the best normal open point for restoration can also depend on the season, day and time.

In the example below, the open point resulting in the least loading of the worst loaded section has been calculated across different time periods. It can be seen that the best normal open point to choose varies between the four normal open points related to that circuit. Adding this degree of sophistication, to consider all the available open points over all the time periods assessed, will allow for a more realistic approach to identifying network constraints.

Variation of best Normal Open Point over time			
Switched out primary number	**Switched out feeder number**	**Restored from branch**	**Count of half hourly periods**
41P0020	9	41D5459_RM01 to 41D5577_RM01 switched in	318
41P0020	9	G71658586 to 41D5688_RM01 switched in	108
41P0020	9	G71665296 to 41D5554_RM01 switched in	4
41P0020	9	N5581106 to 41D5330_RM01 switched in	2

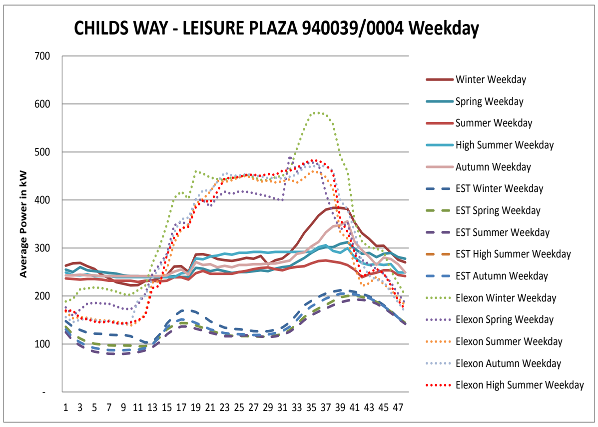
Most Onerous Days

The previous analysis showed a number of feeders for which summer was identified as one of the top three most onerous days.

There is a high degree of agreement between the two sets of analysis with all but two of the feeders originally identified as experiencing some of their most onerous days in Summer being similarly identified in the update. The two feeders with different results relate to errors with one reflecting unrepresentative Elexon estimates and another where the EST estimate appears to lack a component of I&C load.

Feeders originally showing high loading in Summer	Summer still within the most onerous days?
BLETCHLEY>>03 BUCKINGHAM FOODS REDMOOR	Y
BLETCHLEY>>06 THE LINX BLETCHLEY	Y
BLETCHLEY>>07 BEAN HILL NEAPLAND	Y
BLETCHLEY>>09 WHALLEY DRIVE	Y
BLETCHLEY>>11 BURTONS REDMOOR	Y
BLETCHLEY>>13 RANK RADIO INTERNATIONAL	Y
BLETCHLEY>>14 TRADE & MOTORIST CENTRE	Y
BLETCHLEY>>16 IKEA STORE BLETCHLEY	Y
NEWTON ROAD>>03 CRAIGMORE AVENUE BLETCHL	Y
NEWTON ROAD>>06 BUCKINGHAM ROAD BLETCHLE	Y
NEWTON ROAD>>08 SELBOURNE AVENUE MILTON	N – EST model predicts a domestic load pattern rather than I&C dominated
NEWPORT PAGNELL>>07 ALEXANDRA DRIVE NEWPORT	Y
NEWPORT PAGNELL>>10 CRAWLEY ROAD NEWPORT PAG	Y
MARLBOROUGH STREET>>04 FOXHUNTER DRIVE	Y
MARLBOROUGH STREET>>07 MERCEDES-BENZ TONGWELL	Y
MARLBOROUGH STREET>>08 STANTONBURY CHESTNUTS	Y
CHILDS WAY>>04 LEISURE PLAZA	N – Mix of I&C and domestic load
CHILDS WAY>>07 HOMEBASE SNOWDON DRIVE W	Y
CHILDS WAY>>10 CBX4 TEMPORARY SUPPLY	Y
CHILDS WAY>>11 CHILDS WAY LOCAL	Y
CHILDS WAY>>17 BOWLING ALLEY	Y
CHILDS WAY>>21 KNOWLHILL 1	Y
FOX MILNE>>07 FOXMILNE OFFICES TONGWEL	Y

The feeder at Child's Way leisure plaza appears to have been estimated as having a larger component of I&C load within the Elexon estimates, resulting in Summer being among the most onerous days.



Technical learning

Operations were slowed down by the need to calculate and report the headroom values for each section on network so that the section with least headroom could be calculated. This is not expected to slow the operation of the SIM as this will only report items that fail against thresholds.

6. Conclusions & Recommendations

The Authorised Network Model is sufficiently complete to support network analysis. Furthermore, the SIM NMT component is capable of carrying out complex analysis of the kind required for FALCON and can interface to the other elements as required.

The network does not show voltage constraints in normal running or under n-1 conditions, though larger voltage drops are seen under n-1 conditions in this analysis than were seen previously. This should be validated after the Energy Model estimates for industrial and commercial customers have been improved.

Where the load is not overestimated, there are no thermal constraints in normal running though some feeders have relatively high loading levels. Further investigation is required of the two feeders from Newton Rd primary that are shown as having high loadings under normal running to determine whether there are cable sections with incorrectly assigned ratings.

Where the load is not overestimated, there are only two feeders showing overloads for some of the evaluated days under n-1 conditions. Only Newport Pagnell Local requires further investigation. As found by previous analysis this is unlikely to represent a situation which will cause operational limitations in reality as the analysis has been limited to only using one other feeder to backfeed with no additional switching to share load further.

The feeders identified as hotspots for thermal or voltage issues have not generally remained consistent. The other comparators such as average maximum loading and the frequency distributions of results are similar between the two versions of the analysis, where overestimates are excluded.

From the similarity in averages, frequency distributions and the absence of network constraints where load is not overestimated, we can conclude that the components of the SIM are fit for purpose, but that resolving the issue of overestimation by the Energy Model is a high priority.

The Energy Model has improved for modeling domestic customers since forensic workshops held earlier in the year. Results at HV feeder level of domestic dominated feeders are often very similar to the actual SCADA results. The Energy Model can give good results for feeders dominated by industrial and commercial loads or with a mix of loads, but is prone to overestimation of I&C dominated feeders. This is likely to reflect data issues, however this should be confirmed with further forensic workshops focusing on I&C substations. A similar problem was experienced by the Transform model used for ED1 planning. Early versions calculated that significant investment work was required to rectify network issues that it deemed to be already present on the network. These issues were resolved so there are reasons to be optimistic that these can be resolved for the Energy Model too.

Given the large volumes of comparison data available for substations in South Wales it should be possible to determine the degree to which errors in estimation are driven by data quality or errors in the way the data is processed. The installation of monitoring equipment to support the FALCON trials is well underway and also provides data for further validation of the model.

Actions to improve the availability of EAC data have already been suggested and alternative methods to generate realistic annual load estimates where EACs cannot be obtained via the P222 reports need investigation.

The time taken to carry out analysis is greatly affected by whether the analysis is carried out within the IPSA kernel itself or within an exterior scripting layer. Processing in the scripting layer is far slower and while this is not anticipated as being used for the SIM it is worth knowing that any development in this way would have significant impact on performance.