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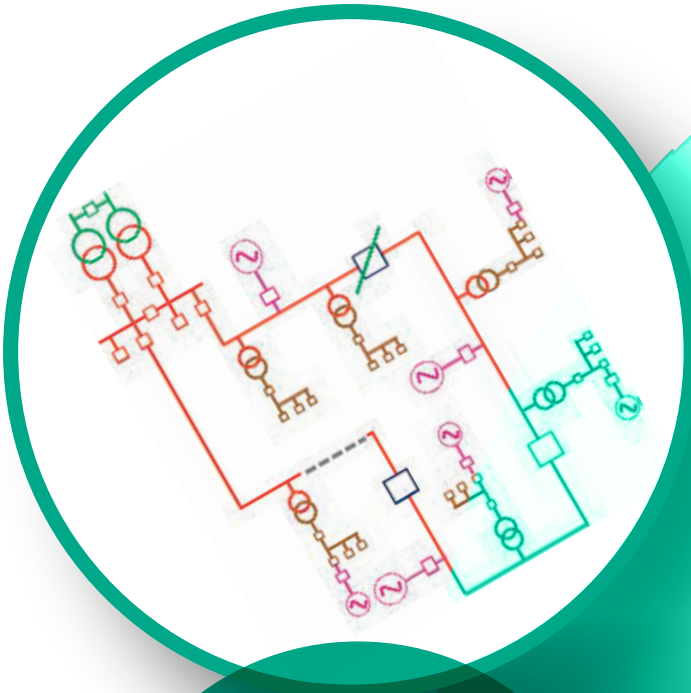
Flexible Networks for a Low Carbon Future



Whitchurch Load Automation Feasibility Assessment

Report No: 7640–02–R2

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CONTENTS

1 Introduction

This preliminary assessment has been carried out by TNEI Services Ltd (TNEI) for Scottish Power Energy Networks (SPEN) in response to a request for a proposal to carry out a load automation feasibility assessment of the Whitchurch 11kV network group. The Whitchurch HV network group is located within the SP Manweb licence area.

This study is to be completed as part of Work Package 2.2 of the Ofgem Low Carbon Networks Fund Tier 2 project "Flexible Networks for a Low Carbon Future". Work Package 2.2 is trialling automated intelligent switching on the secondary (11kV) network and load transfer between primary substations to balance load between adjacent parts of the network, to release capacity and reduce losses. This will also enable improved contingency planning, identify opportunities for network optimisation and increase asset life. Results from the trial will provide proof of concept and quantify the benefits of having this level of network control.

The objective of this assessment is to evaluate the Whitchurch HV group including the neighbouring HV networks to determine whether loadings and the network topography allow for flexible network configurations that improve existing available headroom and reduce losses. The main capacity consideration for the Whitchurch network group is demand capacity. This has been achieved through characterisation of the current loading conditions of the Whitchurch network group and adjacent circuits and power flow studies to quantify the benefits of possible new configurations. Under-voltage issues have also been considered.

In the next phase, the impact of CI/CML philosophy will be assessed and the practical and operational feasibility of additional proposed telecontrol points will be explored. Some additional data analysis has also been identified for selection of further data monitoring/NCP locations.

2 Network Description

2.1 Introduction

Whitchurch is a market town in Shropshire with a population of approximately 9000. There are two 132/33kV grid transformers located at Whitchurch. These two grid transformers are supplied by different 132kV network zones, designated as Cheshire and Wales. A large voltage phase angle difference between these two 132kV supplies exists and therefore the two Whitchurch 132/33kV grid transformers cannot be operated in parallel. The 132/33kV grid transformer supplied from Wales operates in parallel with Oswestry and Marchwiel grid transformers and connects to the 33kV network that supplies the Whitchurch network group and is shown in the figure below. Note that only the 11kV transformers of the Whitchurch network group and adjacent networks are shown for clarity.

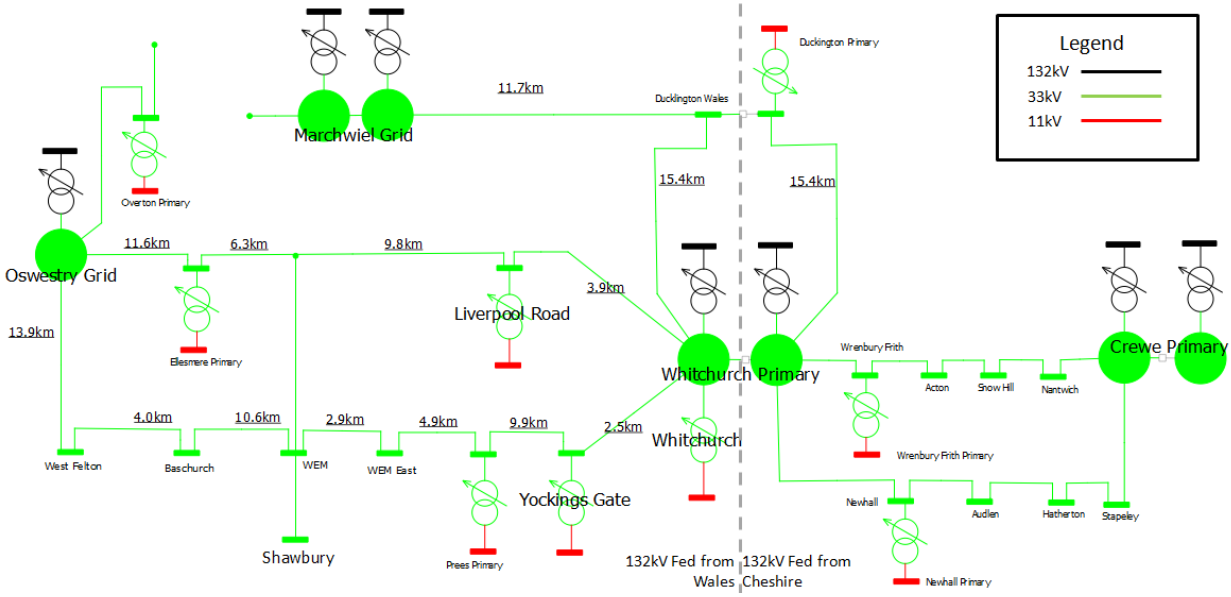


Figure 1 – Whitchurch 132/33kV network

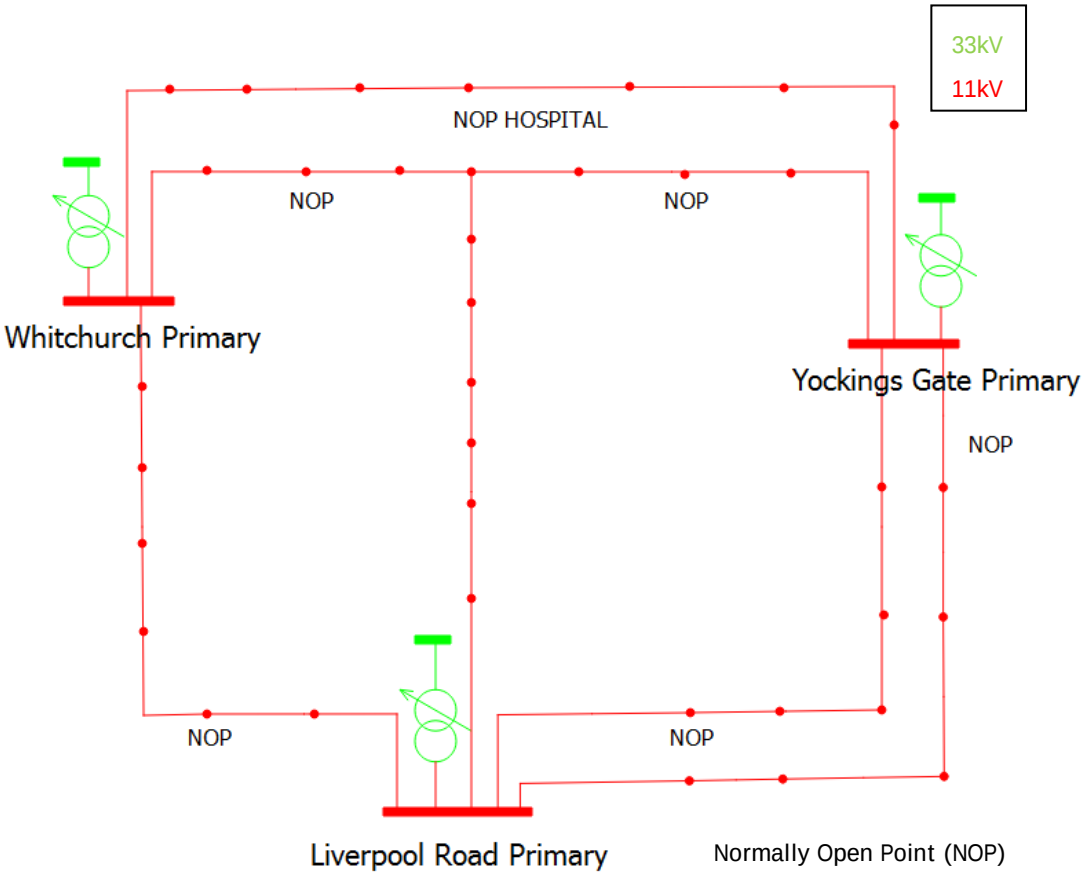


Figure 2 - Whitchurch 33/11kV network

The Whitchurch Network Group is supplied by three 33/11kV primary transformers at Whitchurch, Liverpool Road and Yockings Gate, as shown in Figure 2. The Whitchurch transformer has a rating of 10MVA (ONAF) and the Liverpool Road and Yockings Gate transformers have a rating of 7.5MVA (ONAN) and a short term cyclic rating of 10 MVA. This provides a theoretical firm capacity of 20 MVA to the 11kV network group during an outage of any one of the three transformers (to satisfy distribution network planning standards). In this "N-1" configuration, supply can be met via the other transformers in the group and via remote ends from other 11kV network groups if necessary. Cable circuits in the 11kV Whitchurch network group are assumed to have a continuous rating of 3.6MVA or 189A. Overhead line circuits are assumed to have a continuous rating of 3.33MVA or 175A.

The 11kV circuits from these primary transformers are operated radially but with the facility to be interconnected following a system outage. Interconnection is achieved by closing an 11kV switch or circuit breaker that is normally operated open and is referred to as the normally open point (NOP). These are manually operated in the Whitchurch network group.

Adjacent 11kV networks with capability for interconnection are Prees, Ellesmere and Overton. These networks are supplied by the same 33kV network as the Whitchurch network group. Other adjacent 11kV networks with capability for interconnection are Duckington, Wrenbury Frith and Newhall. These 11kV

networks are supplied by the Cheshire 132kV system and hence may not be suitable for load transfer due to voltage phase angle differences. The 11kV Whitchurch network group together with interconnecting feeders from adjacent network groups and NOPs, is shown in the diagram below. For clarity, the diagram does not show feeder spur details or feeders from adjacent networks that do not interconnect to the Whitchurch network group. The theoretical firm capacity for each substation group is also shown.

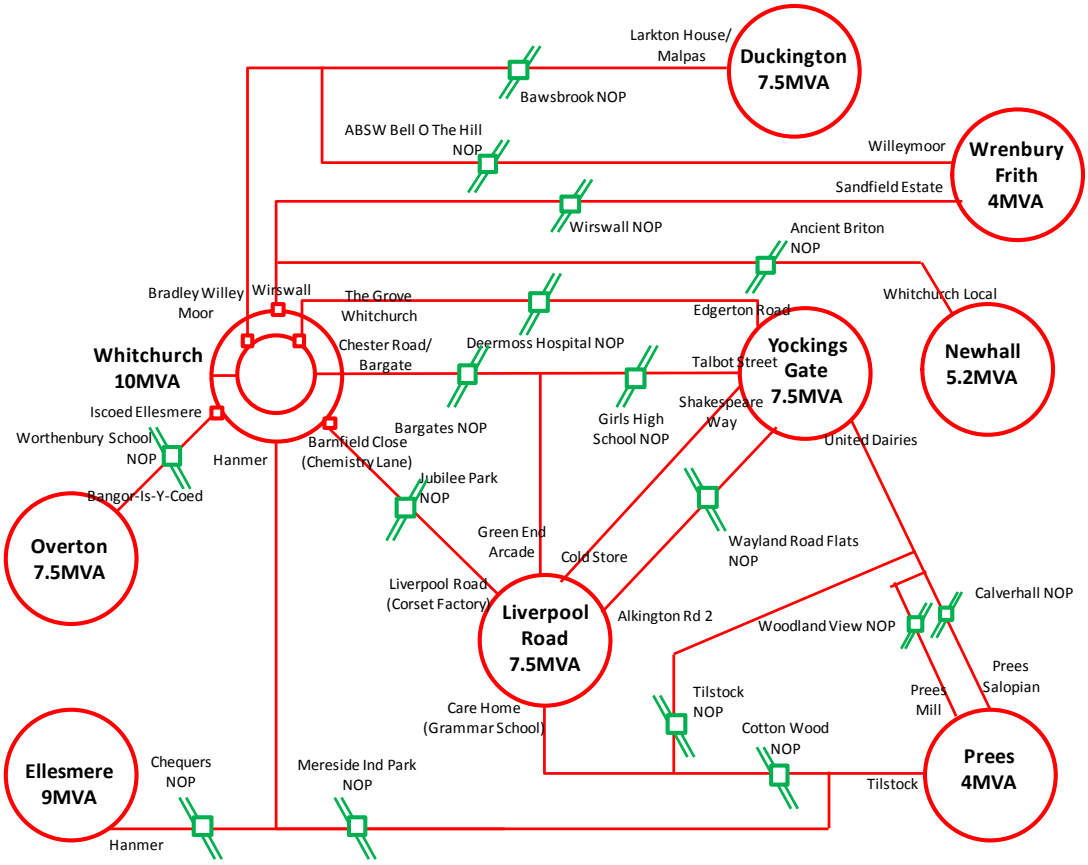


Figure 3 - 11kV Whitchurch network group and adjacent networks

The Cold Store-Shakespeare Way feeder in Figure 3 between Liverpool Road and Yockings Gate primaries has been operational since 02/11/2011. The Cold Store 11kV load (2.35MVA demand) on the Yockings Gate Station Road feeder and Shakespeare Way secondary substation (ground mounted transformer of 500kVA capacity) on the Liverpool Road Green End Arcade feeder were moved to the Cold Store-Shakespeare Way feeder. From analysis of PI data, this feeder appears to be predominantly supplied from Liverpool Road.

The Station Road feeder was previously identified (in 2010) as a headroom constraint within the Whitchurch network group for connection of additional load in the vicinity. This has been alleviated with the addition of the Cold Store-Shakespeare Way feeder.

Please note that there are thermal and voltage limitations on the 33kV network supplying the Whitchurch network group. Various reinforcement options to resolve these are under consideration by SPEN. This suggests that temporary or

permanent load transfer from the Whitchurch network group to adjacent networks within the Cheshire area as shown in Figure 1 may be beneficial in mitigating 33kV network issues.

2.2 Theoretical Group Headroom

The theoretical group firm capacity for the Whitchurch network group and adjacent 11kV networks is shown in the table below, reproduced from the 2011/2012 SPM Long Term Development Statement (LTDS) and discussions with SPEN. Group firm capacity is based on supply capability following the loss of one transformer (N-1) in order to satisfy the distribution network planning standard Engineering Recommendation P2/6. Supply under this scenario can be via other transformers in the 11kV network group or supply through remote ends from other 11kV groups. Theoretical group headroom is also calculated based on the maximum load of the previous year. It should be noted that the Prees transformer has a rating of 7.5MVA however we understand from SPEN that there may be voltage limitations on the network that reduce the theoretical capacity to 4MVA.

Table 1 - Theoretical 11kV network group firm capacity

S/S Group	S/S Name	Voltage Level	Maximum Load of Previous Year (2012/2013)			Forecast Load Information					Group Firm Capacity	% Theoretical Network Headroom
						2013 / 2014	2014 / 2015	2015 / 2016	2016 / 2017	2017 / 2018		
		kV	MW	MVAr	MVA	MVA					MVA	
DUCKINGTON	Duckington	11	5.02	0.80	5.08	5.34	5.60	5.88	6.18	6.49	7.5	32%
NEWHALL	Newhall	11	2.14	1.03	4.26	4.47	4.69	4.93	5.17	5.43	5.2	18%
	Newhall		1.91	0.24								
WRENBURY FRITH	Wrenbury Frith	11	3.60	0.75	3.68	3.86	4.05	4.26	4.47	4.69	4	8%
ELLESMERE - MMB ELLESMERE	Ellesmere	11	3.85	1.32	7.65	8.03	8.43	8.85	9.30	9.76	9	15%
	MMB Ellesmere		3.64	0.22								
LIVERPOOL RD WHITCHURCH YOCKINGS GATE	Liverpool Rd	11	4.28	0.56	16.58	17.40	18.27	19.19	20.15	21.15	20	17%
	Whitchurch		7.27	1.50								
	Yockings Gate		4.77	0.84								
OVERTON	Overton	11	3.76	0.69	3.82	4.01	4.21	4.42	4.64	4.88	7.5	49%
PREES	Prees	11	5.07	1.02	5.17	5.43	5.70	5.98	6.28	6.60	4	-29%

2.3 Whitchurch Network Group Operation under N-1 Conditions

The operation of the Whitchurch network group under contingency conditions is explored below. This is based on observations from PI data.

2.3.1 Whitchurch 11kV Network

Whitchurch is configured with a double busbar arrangement as shown in Figure 4 below. This configuration provides the flexibility to backfeed from other feeders

in the Whitchurch 11kV network during outage of the primary transformer. From investigation of PI data, feeders may also be backfed from interconnecting feeders with adjacent network groups including Overton, Ellesmere, Newhall and Wrenbury Frith. Feeder circuit breakers at Whitchurch primary substation would presumably be triggered to prevent voltage phase angle differences in the Cheshire 132kV network from detrimentally influencing power flow in the Wales network (for backfeed from Newhall or Wrenbury Frith).

From analysis of PI data, there appears to be several backfeeding arrangements from the Whitchurch network group across the double busbars.

- Supply of Hanmer and Iscoed Ellesmere feeders using Chester Road/Bargates (from Liverpool Rd primary substation)
- Supply of Bradley Willey Moor and Wirswall feeders using The Grove feeder (from Yockings Gate substation)

These arrangements require both busbars and hence the buscoupler must be closed. SPEN indicate that the specific backfeed arrangement would be selected by network operations in the event of any outage or for maintenance over the summer, depending on the loading of other substations at the time.

Other Whitchurch feeders can be backfed from interconnecting feeders within the Whitchurch network group.

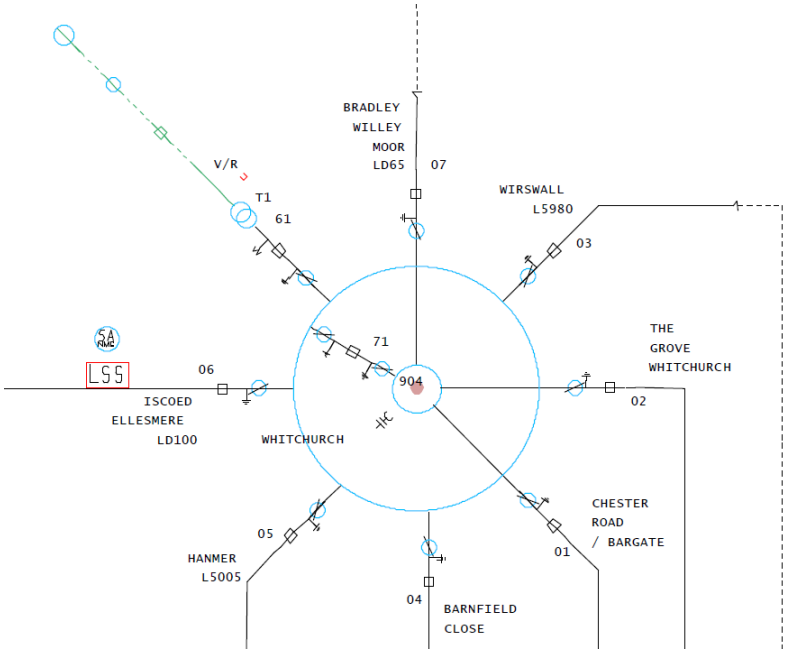


Figure 4 - Whitchurch primary substation 11kV busbar arrangement

2.3.2 Yockings Gate 11kV Network

For Yockings Gate, under loss of the primary transformer, the circuit breakers on all feeders are triggered and feeders are generally backfed from interconnecting feeders within the Whitchurch network group.

From analysis of PI data there appears to be several backfeed arrangements for the United Dairies feeder with the loss of the Yockings gate primary transformer:

- Supply of United Dairies feeder using Liverpool Road Grammar School (from Liverpool Rd primary substation)
- Supply of United Dairies feeder using Prees Salopian feeder (from Prees primary substation)

2.3.3 Liverpool Road 11kV Network

For Liverpool Road, under loss of the primary transformer, the circuit breakers on all feeders are triggered and feeders are generally backfed from interconnecting feeders within the Whitchurch network group.

Figure 5 shows the network control points on the Green End Arcade/ Alkington Road No 1 feeder. This feeder can be backfed from Whitchurch and/or Yockings Gate through closure of the NOPs at Bargates and Girls High School or with operation of Telecontrol points at Green End Arcade and Alkington Road No 1. The Telecontrol points at Green End Arcade and Alkington Road No 1 seem to have been used during an N-1 at Liverpool Road on 02/10/2011.

From analysis of PI data there appears to be several backfeed arrangements for the Grammar School feeder with the loss of the Liverpool Road primary transformer:

- Supply of Grammar School feeder using Yockings Gate United Dairies feeder (from Yockings Gate primary substation)
- Supply of Grammar School feeder using Prees Tilstock feeder (from Prees primary substation)

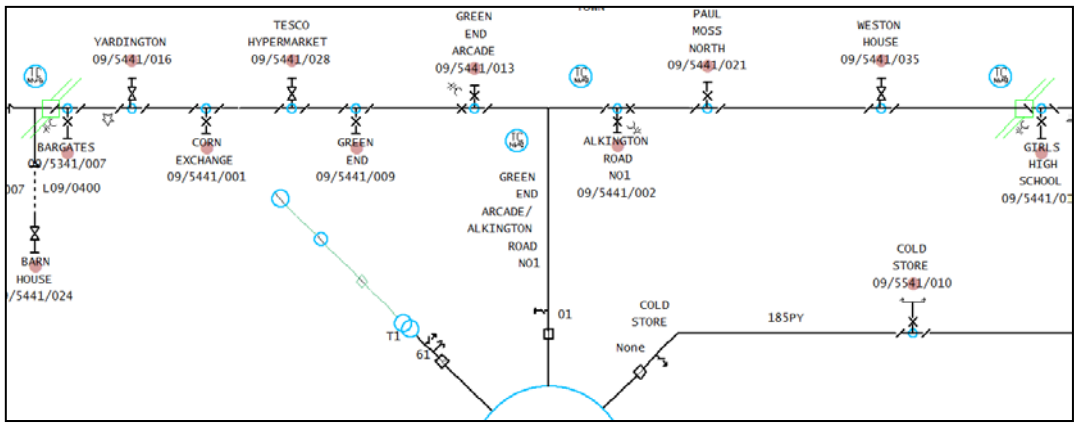


Figure 5 - Liverpool Road Green End Arcade / Alkington Rd No 1 network control points

2.4 Network Control Points

Network control points for the Whitchurch network group are shown in Figure 6. This indicates manual telecontrol points and secondary automation (telecontrol) points, which can be operated from the control centre.

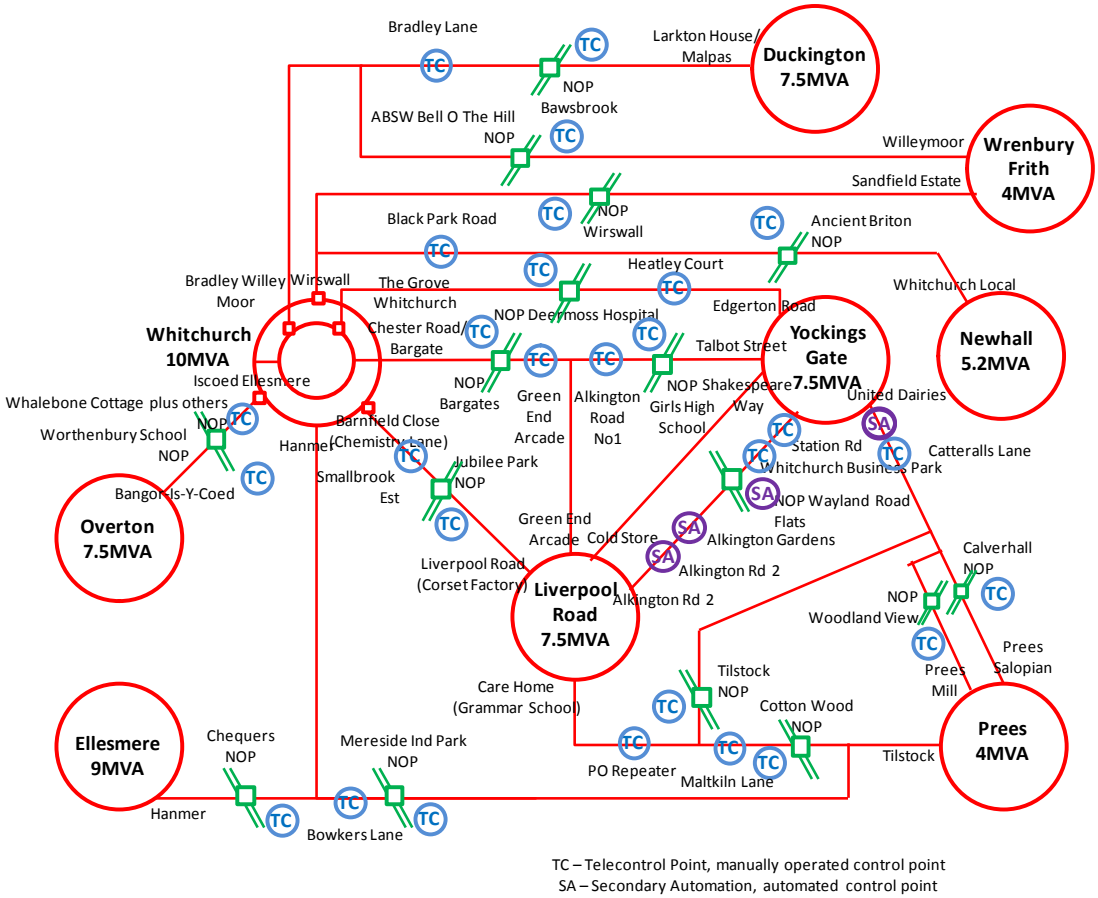


Figure 6 - Network control points

2.5 CI & CML

Customer Interruptions (CI) and Customer Minutes Lost (CML) are critical parameters when optimising network NCP location. The number of customers on each feeder up to the existing NOPs is shown in Figure 7.

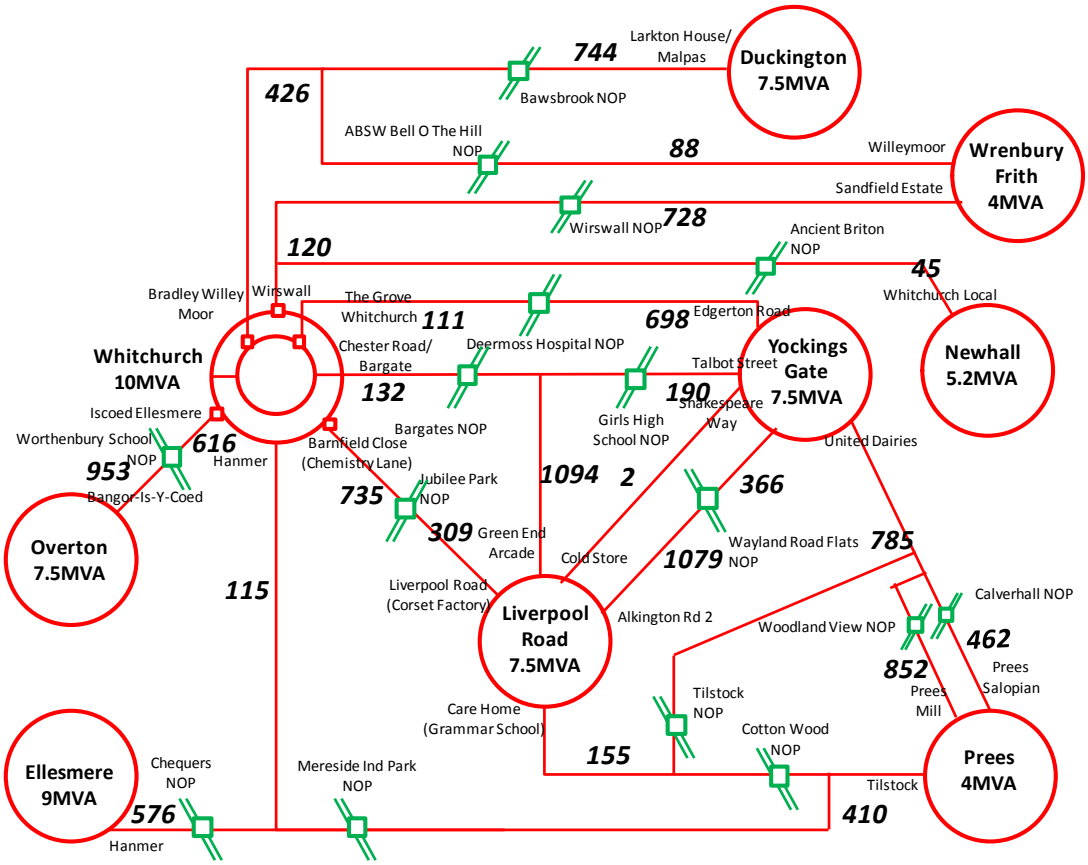


Figure 7 - Customer Numbers

This will be considered in more detail in the next phase of the assessment, for proposed additional NCP locations.

3 Methodology

The methodology used to identify and assess potential load transfer opportunities is described below.

Opportunities for improvement of load transfer may be through either;

- Temporary or permanent load transfer to interconnecting feeders within the Whitchurch network group from highly loaded feeders to low loaded feeders (only suitable for T connections). There are no load transfer opportunities for additional telecontrol points on radial feeders within the Whitchurch network group that are resupplied from the other end in the event of transformer outage e.g. Alkington Rd No 2 and Station Rd. Although it is recognised that there may be CI/CML benefits during circuit outages.
- Temporary load transfer to interconnecting feeders in adjacent network groups during periods of concurrent high loading on Whitchurch network group feeders and low loading on interconnecting feeders.
- Temporary or permanent load transfer to low loaded interconnecting feeders in adjacent network groups where there is sufficient headroom on the adjacent network group.

Load transfer improvement can be achieved by adding further normal control points (NCPs) on the Whitchurch network group feeders. This adjustment should enable transfer of load to the lightly loaded interconnecting feeder and reduction of load on the Whitchurch network group feeder, achieving an effective increase in headroom capacity under N-1 conditions.

As indicated earlier, load transfer from the Whitchurch network group to adjacent networks within the Cheshire area may also be beneficial in mitigating Whitchurch network issues at 33kV.

3.1 Primary Transformer Analysis

Load distribution for the primary transformers in the Whitchurch network group in 2012 was assessed to explore current loading characteristics and distribution of load.

3.2 Feeder Current Analysis

Feeder current profiles were analysed for Whitchurch network group feeders and interconnecting feeders using PI data for instantaneous 11kV feeder currents from 2010 to 2012. The maximum load conditions that exist on each feeder in the Whitchurch network group under normal conditions were identified.

The daily current profile for Whitchurch network group feeders and associated interconnected feeders were plotted on the date when maximum loading was measured. Load transfer opportunities are optimal when the peak daily load on a

highly loaded Whitchurch network group feeder coincides with a period of reduced loading on an interconnected feeder.

The average daily load profile for the week, month and three month period centred on the most highly loaded date were also assessed where appropriate to explore longer term load profile characteristics. The standard deviation of the average daily load profile was plotted to give an indication of variation of the daily profile over the averaging time period.

Comparison of daily load profiles enabled identification of potential load transfer opportunities and possible location of additional NCPs.

3.3 IPSA Modelling

An IPSA model of the 11kV Whitchurch network group and interconnecting feeders on adjacent networks was developed to calculate feeder loading under N-1 conditions for the existing and proposed network topology. This enables quantification of loading reduction for the proposed new network topology with additional NCPs.

The model loading conditions were scaled to represent as closely as possible, maximum feeder current conditions in a normal configuration for each load transfer opportunity identified. A power flow analysis was then run for N-1 various configurations which comprise the loss of one of the Whitchurch Primary transformer, Liverpool Road Primary transformer or the Yockings Gate Primary transformer. A target voltage of 1pu was assumed at the primary transformers.

The resulting current flows and loading were used to determine the existing available headroom and the improvement in headroom based on a network group topology with the new NCP locations. Feeder voltage profile was also considered for new NCP locations to ensure that statutory 11kV voltage limits were not at risk of being exceeded.

3.4 Headroom Assessment

The thermal headroom for the Whitchurch network group was assessed on the basis of the maximum loading for each primary transformer during an N-1 condition, for maximum aggregate Whitchurch network group load, using the formula below:

$$Headroom\% = \frac{Capacity(MVA) - Load\ @\ N-1}{Capacity(MVA)}$$

Thermal headroom was first benchmarked for each primary transformer on the basis of the current network configuration. Thermal headroom was then assessed for the proposed new network configuration to quantify benefits due to use of additional NCPs.

Theoretical firm capacity for the network group is generally based on a distribution of load across two primary transformers during outage of the other primary transformer that corresponds to the individual transformer capacity. The analysis provides an indication of load distribution between the primary transformers in the network group and opportunities to improve this.

Voltage drop was also considered for the current and proposed network configuration to ensure that statutory limits were not exceeded during N-1.

Feeder headroom was assessed to ensure that there are no significant thermal constraints in the network during N-1 conditions.

It should be noted that the actual available network and feeder headroom will be influenced by both the size of new load and generation connections and proposed connection location.

4 Primary Transformer Analysis

4.1 Distribution of Network Group Loading

Primary transformer daily loading profiles for the highest aggregate load (14.06MVA) observed in 2012 are shown in Figure 8. Data availability for Whitchurch network group primary transformers in 2012 was close to 100%.

It can be seen that loading for Whitchurch and Liverpool Rd is broadly similar with Yockings Gate indicating lower loading. This is similarly reproduced in the annual average primary transformer daily loading in Figure 10. Yockings Gate primary transformer has a rated capacity 2.5MVA less than Whitchurch and Liverpool Road. Adjacent networks also show high loading for this day in Figure 9. Please note that the loading for the Ellesmere primary transformer group is based on twice the loading of a single transformer as data was not available for both primary transformers.

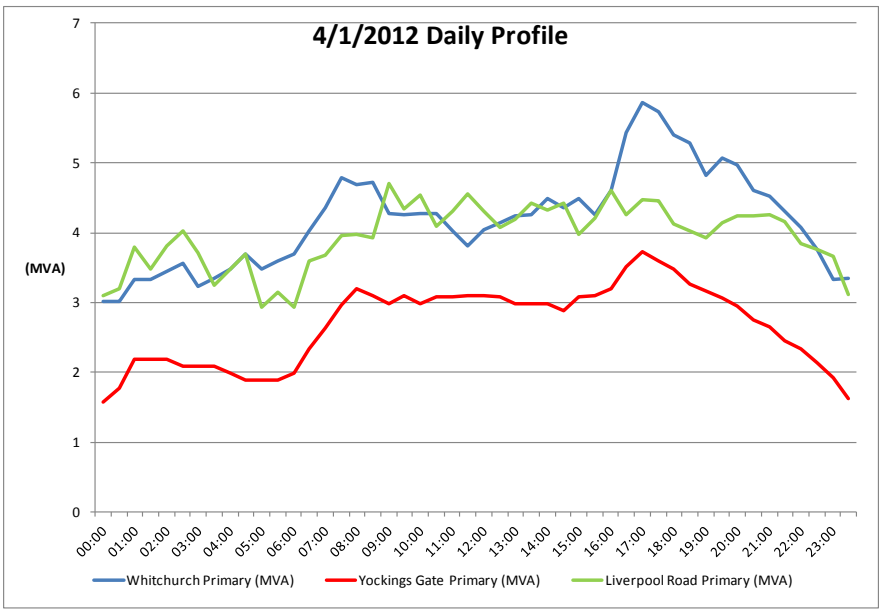


Figure 8 – Maximum primary transformer daily loading 2012 (for aggregate Whitchurch network group load)

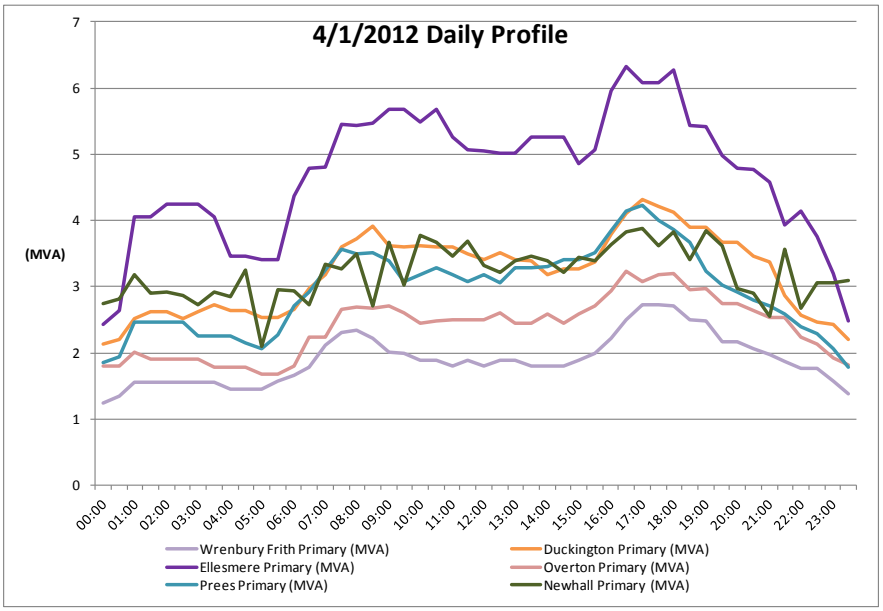


Figure 9 – Daily loading 2012 for adjacent networks for maximum aggregate Whitchurch network group load

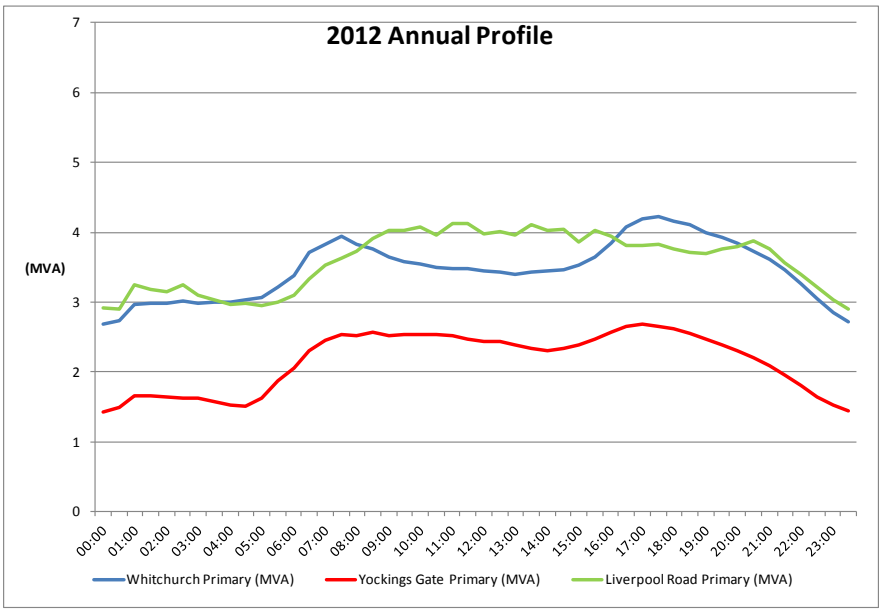


Figure 10 – Average primary transformer daily loading 2012

4.2 Distribution of Network Group Loading during N-1

Primary transformer daily loading profiles during various outage conditions are shown below. It can be seen that during an outage of Yockings Gate, the loading is relatively evenly distributed between Whitchurch and Liverpool Road although Liverpool Road initially appears to pick up more load than Whitchurch.

During an outage of Whitchurch, Liverpool Road picks up proportionally more load than Yockings Gate however as mentioned, Yockings Gate primary transformer has a lower rated capacity. There may be opportunities for re-distributing some load from Whitchurch and Liverpool Road to Yockings Gate to improve load distribution across the network group and increased thermal headroom.

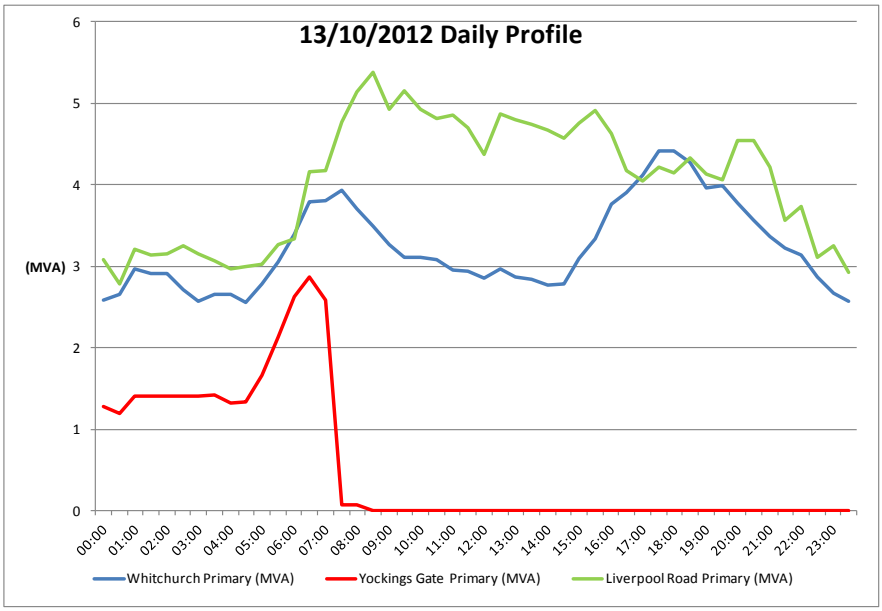


Figure 11 - Primary transformer daily loading during outage of Yockings Gate

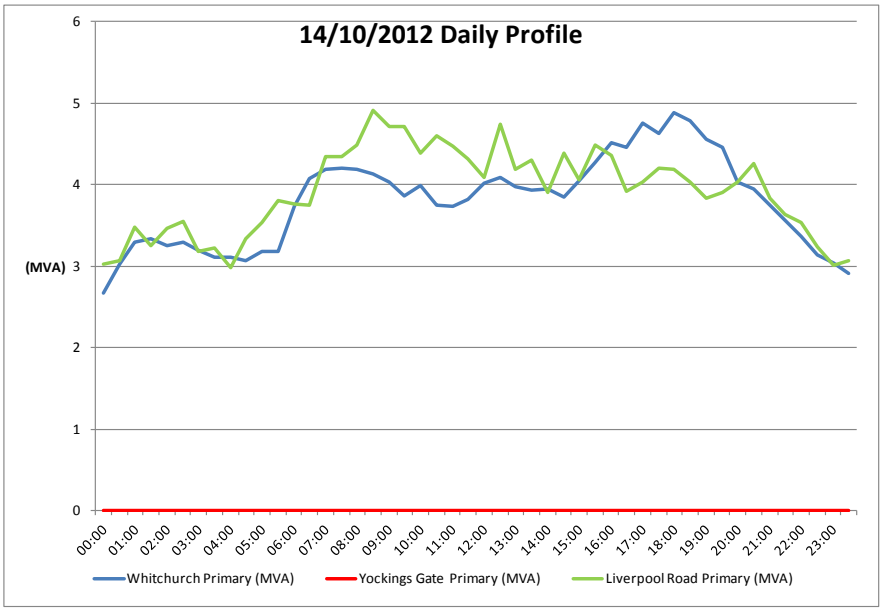


Figure 12 - Primary transformer daily loading during outage of Yockings Gate

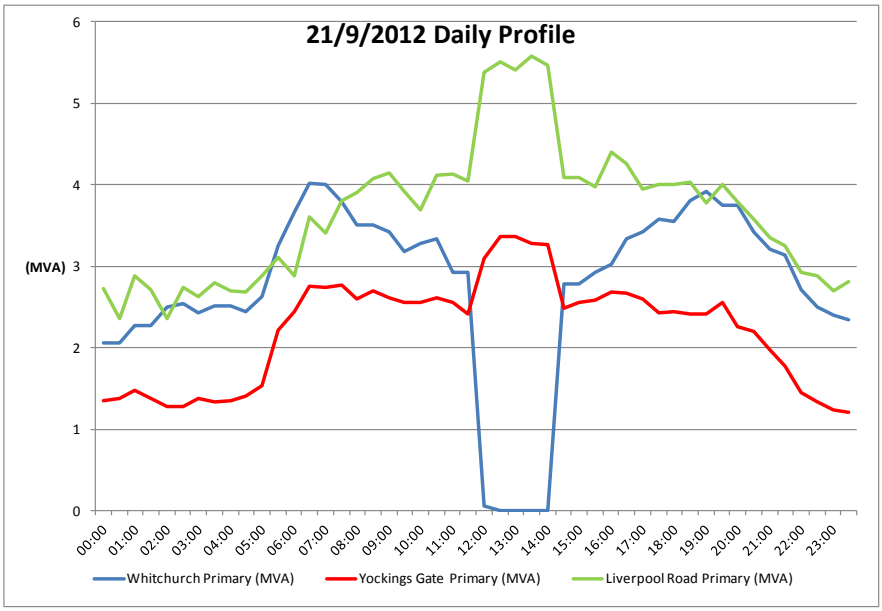


Figure 13 - Primary transformer daily loading during outage of Whitchurch

4.3 Load Duration

Load duration curves for 2012 for the Whitchurch network group primary transformers are shown in Figure 14. Load duration curves for 2012 for the adjacent network primary transformers are shown in Figure 15.

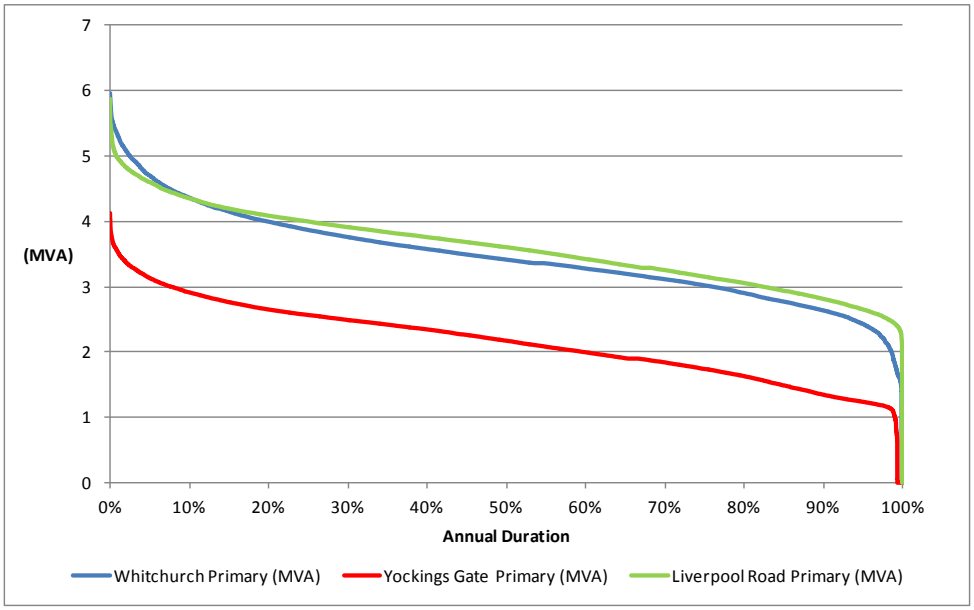


Figure 14 - Primary transformer load duration 2012 for Whitchurch network group transformers

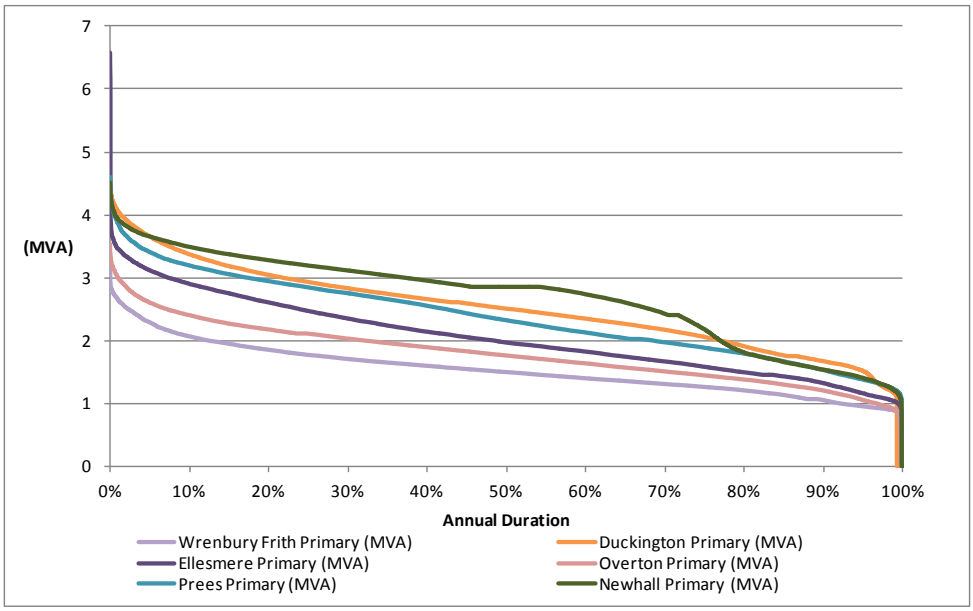


Figure 15 – Primary transformer load duration 2012 for adjacent network primary transformers

5 Feeder Current Analysis

5.1 Maximum Loading Conditions

Table 2 summarises the maximum instantaneous currents and associated timestamp that have been observed on feeders with potential for load automation in the Whitchurch network group. Instantaneous currents for interconnecting feeders at the same timestamp are also provided. These are taken from PI data covering 2010, 2011 and 2012.

Data availability for each feeder was generally reasonable between 2010 and 2012. Average feeder current for 2010 to 2012 was consistent with average feeder current in 2012 which had very good data availability.

Table 2 - Maximum Instantaneous Currents

Whitchurch Network Group Load Transfer Opportunity	Interconnecting Feeders	Timestamp	Maximum Instantaneous Current (A)	Average Current 2010-2012 (A)
Whitchurch Network Group	Liverpool Road~Green End Arcade	07/12/2010 10:30	137	70
	Whitchurch~Bargates	07/12/2010 10:30	8	5
	Yockings Gate~Talbot Street	07/12/2010 10:30	12	6
Whitchurch~Bradley Willey Moor	Whitchurch~Bradley Willey Moor	07/12/2010 18:00	56	27
	Duckington~Larkton House/Malpas	07/12/2010 18:00	85	46
	Wrenbury Frith~Willeymoor	07/12/2010 18:00	3	3
Whitchurch~Wirswall	Whitchurch~Wirswall	07/12/2011 12:30	33	14
	Wrenbury Frith~Sandfield Estate	07/12/2011 12:30	19	44
	Newhall~Whitchurch Local	07/12/2011 12:30	9	2
Yockings Gate~Whitchurch United Dairies	Yockings Gate~Whitchurch United Dairies	20/12/2010 18:30	116	49
Liverpool Road~Care Home Grammar	Liverpool Road~Care Home Grammar	20/12/2010 18:30	15	7
	Prees~Prees Salopian	20/12/2010 18:30	76	41
	Prees~Prees Mill	20/12/2010 18:30	100	57
	Prees~Tillstock	20/12/2010 18:30	41	20
Whitchurch~Hanmer	Whitchurch~Hanmer	18/11/2010 17:30	126	56
	Prees~Tillstock	18/11/2010 17:30	32	20
	Ellesmere~Hanmer	18/11/2010 17:30	8	36
Whitchurch~Iscoed Ellesmere	Whitchurch~Iscoed Ellesmere	20/12/2010 18:00	110	47
	Overton~Bangor-Is-Y-Coed	20/12/2010 18:00	115	50

The following sections explore the potential load transfer opportunities in further detail.

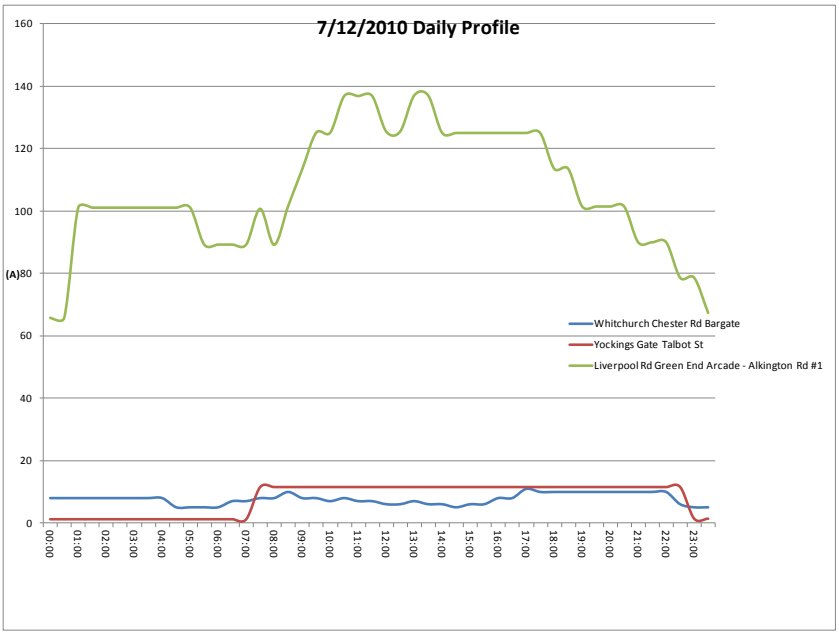
5.2 Load Transfer within Whitchurch Network Group

There may be an opportunity for load transfer within the Whitchurch network group for the T connection on the Liverpool Road Green End Arcade feeder. The maximum instantaneous current and average current in Table 2 show that the Liverpool Road Green End Arcade feeder is typically the most heavily loaded feeder in this feeder group.

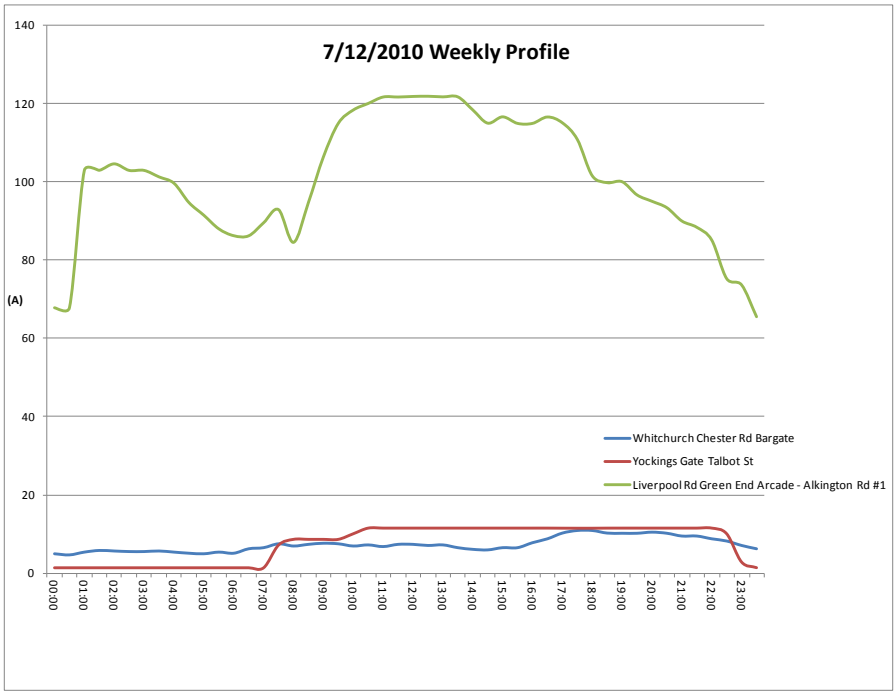
During an N-1 condition, the load on the Liverpool Road Green End Arcade feeder is resupplied by either the Whitchurch or Yockings Gate primary. Additional NCPs between the NOPs at Bargates (Whitchurch) and Girls High School (Yockings Gate) and Liverpool Road primary would enable improved distribution of load during an outage. Existing telecontrol points at Green End Arcade and Alkington Road No 1 could be utilised to achieve this. Moving the NOP permanently to transfer more load to Yockings Gate from Liverpool Road should also be considered as this may help to improve the headroom.

5.2.1 Whitchurch~Bargates | Liverpool Road~Green End Arcade | Yockings Gate~Talbot Street

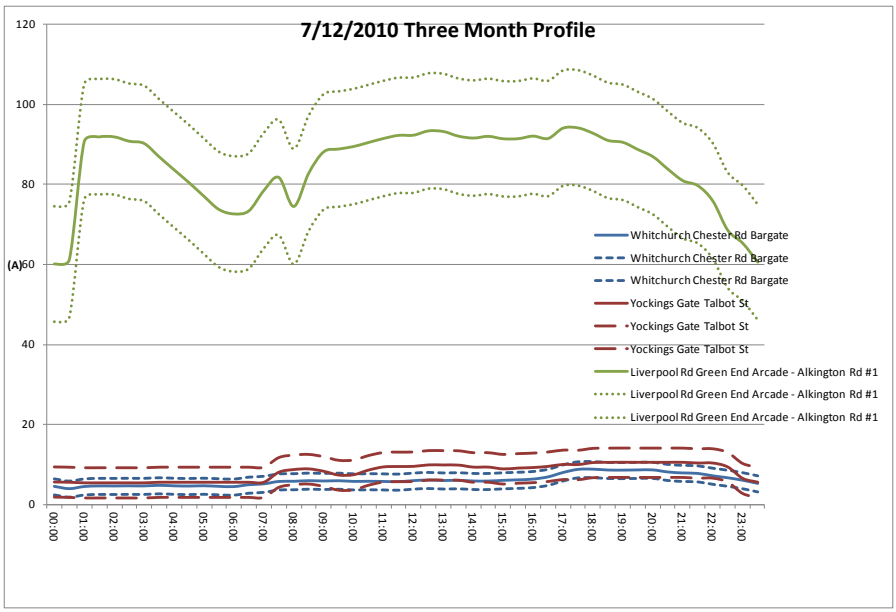
Maximum currents on the Liverpool Road Green End Arcade feeder are observed on the 7/12/2010 and are shown on the daily profile below.



The average weekly and three-monthly daily profiles for this maximum loading condition are also plotted and show similar behaviour. This indicates that there may be potential for improved load distribution under N-1 based on new control points.



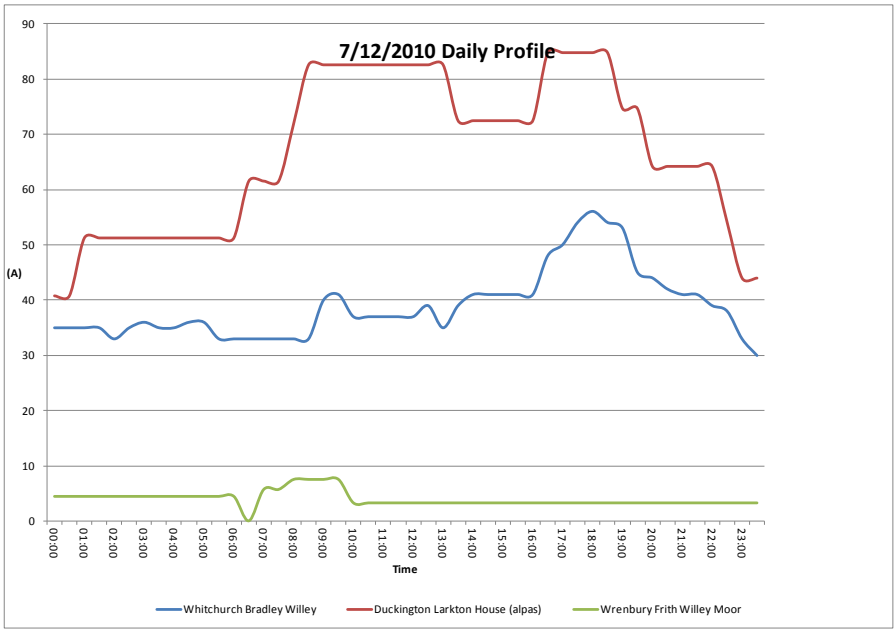
The monthly profile matches this trend. The chart below shows the average three month profile, along with the profile standard deviation.

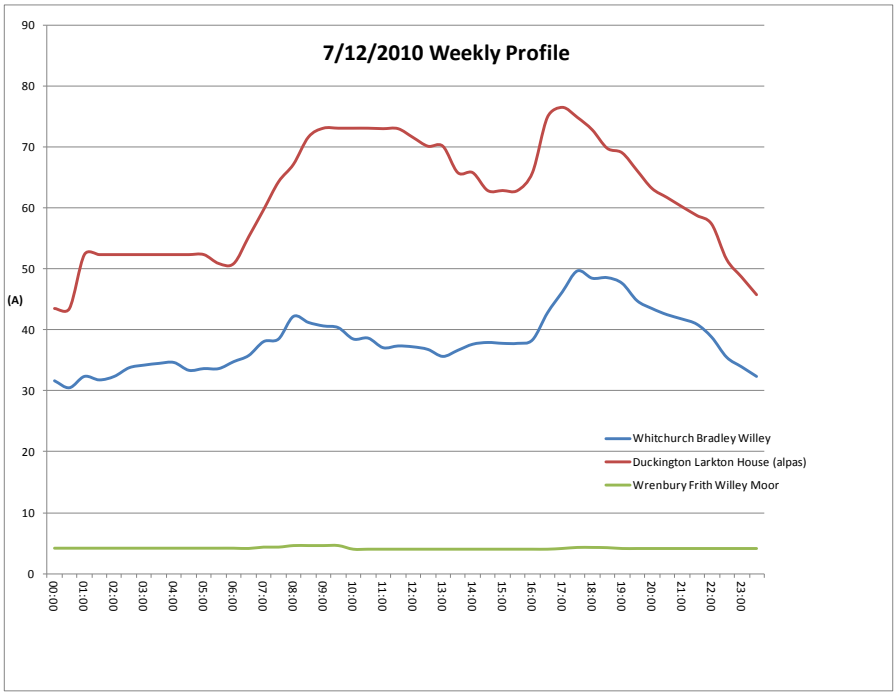


5.3 Load Transfer to Adjacent Networks

5.3.1 Whitchurch~Bradley Willey Moor Feeder

There may be opportunity to use a network control point to reduce the load on the Whitchurch~Bradley Willey Moor feeder. This would be achieved by adding a NCP near the NOP at Bawsbrook on the Duckington~Larkton House feeder or near the NOP at Bell O The Hill on the Wrenbury Frith~Willeymoor feeder.



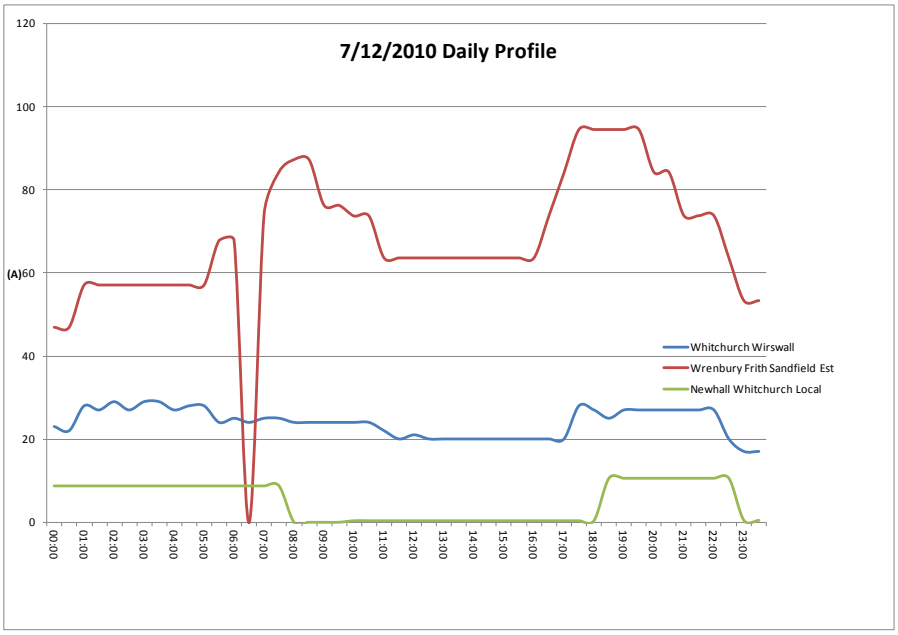


The plots show that the currents on the Whitchurch~Bradley Willey circuit are lower than the Duckington~Larkton House feeder. The possibilities for load transfer from the Whitchurch~Bradley Willey circuit are hence limited to the Wrenbury Frith~Willey Moor feeder. However, the limited variation in daily load on the Wrenbury Frith~Willey Moor feeder suggests that load transfer from Whitchurch could result in potentially result in an increase of maximum demand on the Wrenbury Frith primary, eroding the network headroom.

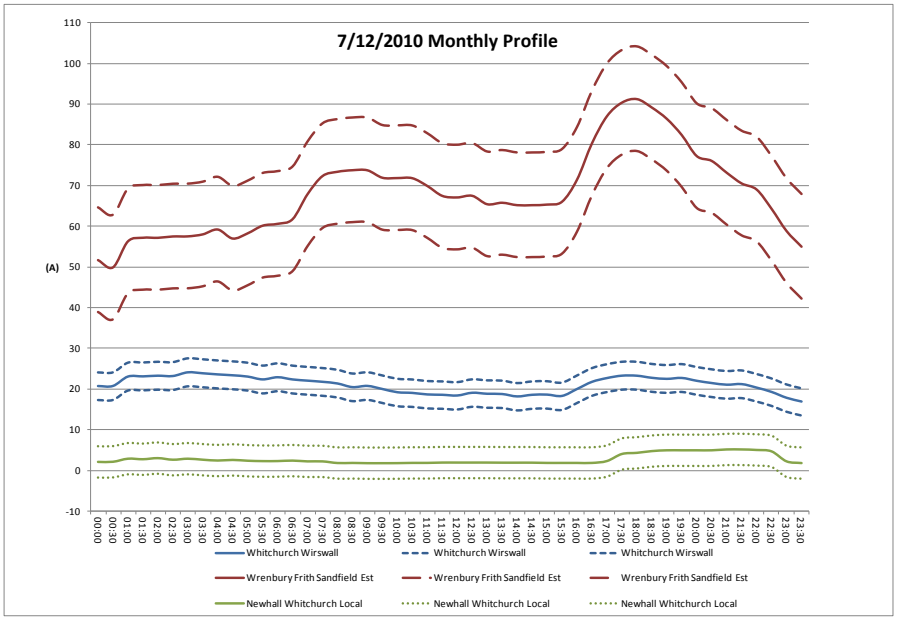
Also, the Wrenbury Frith primary substation is fed from the Cheshire 132kV network and may be unsuitable for use in load automation depending on flows during switching sequences.

5.3.2 Whitchurch ~Wirswall Feeder

The maximum instantaneous current on the Whitchurch~Wirswall feeder was observed on 07/12/2010. The profile for Newhall Whitchurch feeder suggests a possible outage condition which we have not been able to verify.



The monthly average daily profile indicates a similar trend in feeder current daily profile.



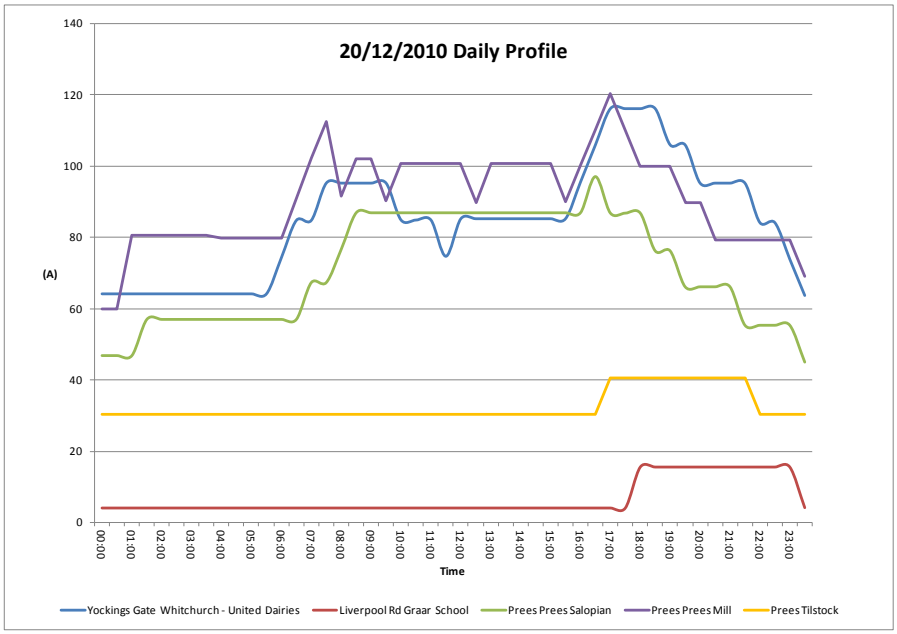
Load transfer opportunities are limited for the Whitchurch~Wirswall feeder due to relatively low currents on this feeder unlikely to provide headroom improvements for the Whitchurch network group.

The Newhall primary substation is fed from the Cheshire 132kV network and may be unsuitable for use in load automation depending on flows during switching sequences.

5.3.3 Yockings Gate~United Dairies and Liverpool Road~Grammar School Feeders

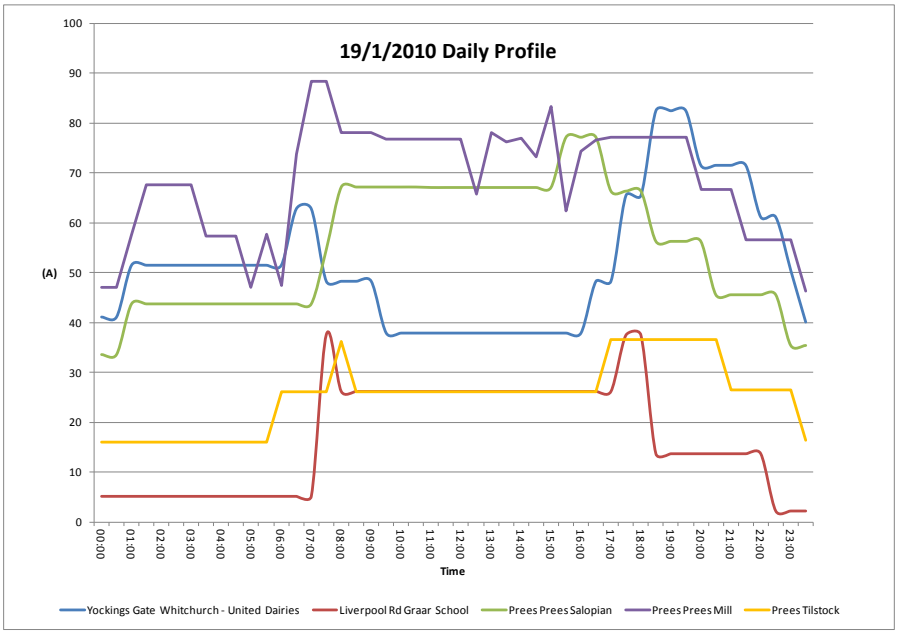
The Yockings Gate~United Dairies feeder has connectivity to the Liverpool Road~Grammar School feeder and to two feeders on the Prees network. Prees Salopian and Prees Mill may provide opportunities for load transfer.

Analysis of feeder currents shows that the maximum instantaneous current on the United Dairies feeder was observed on 20/12/2010. The daily profile is shown below.

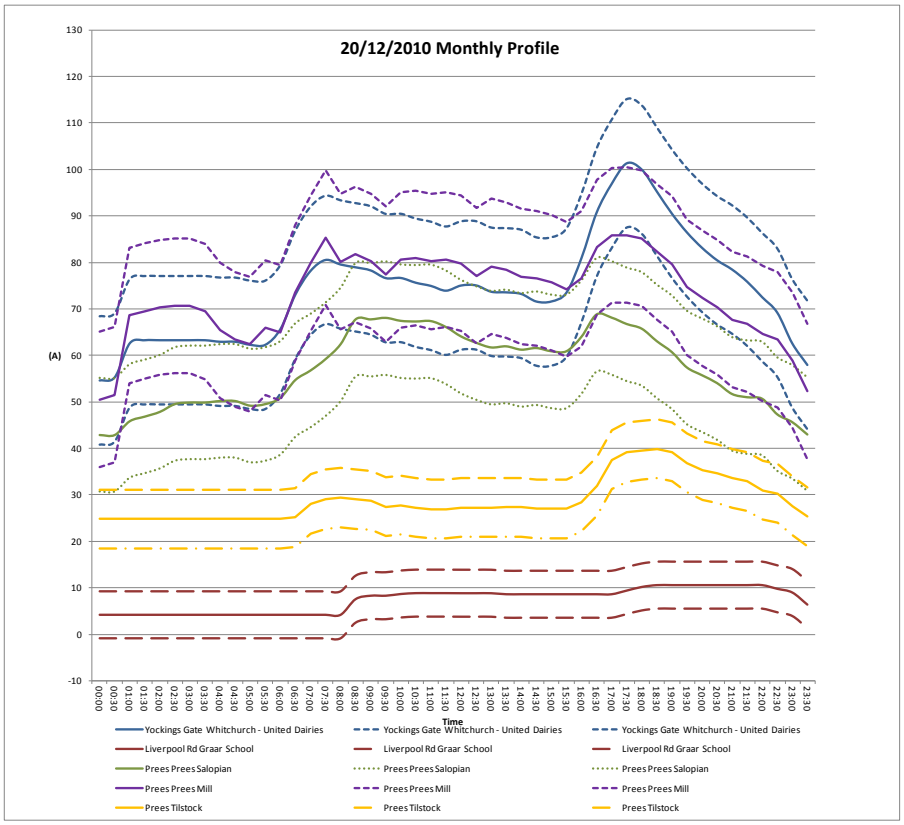


It can be seen that the daily current profiles on the United Dairies, Prees Salopian and Prees Mill feeders are similar in magnitude and peak load period.

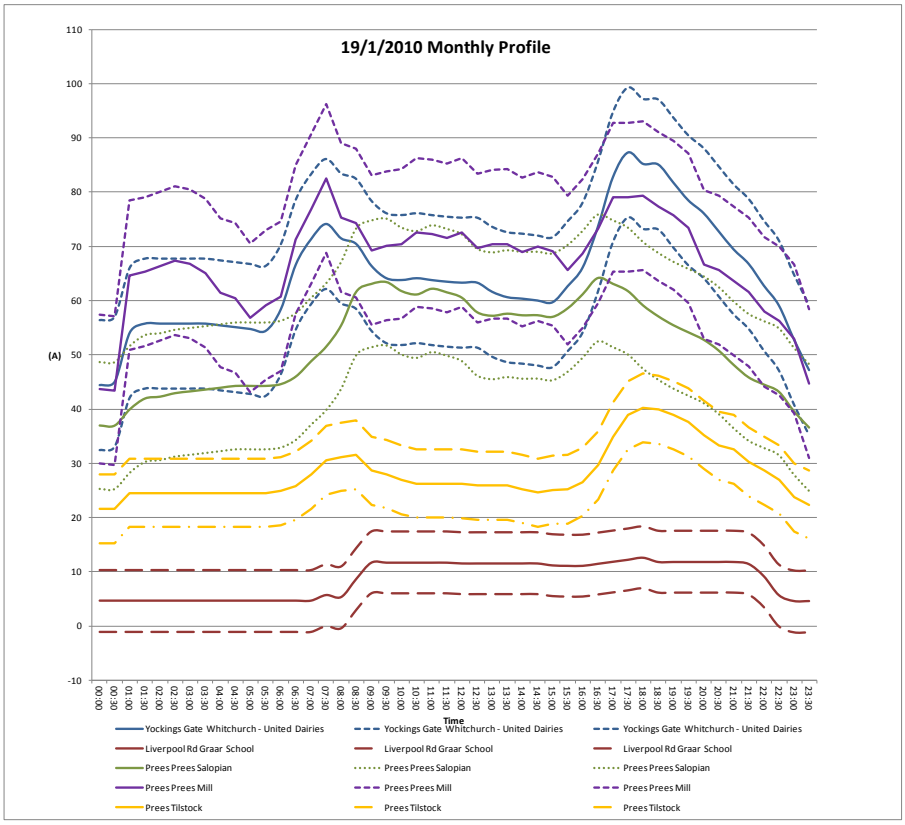
The maximum instantaneous current for the Liverpool Road~Grammar School feeder was observed on the 19/1/2010 and is shown below although it appears that there may be some load transfer occurring on this date between Prees~Salopian and Yockings Gate~united Dairies.



The monthly average load profile around the 20/12/2012 shown below suggests again that the load transfer opportunities will be limited because the peak load periods on each feeder are very similar.



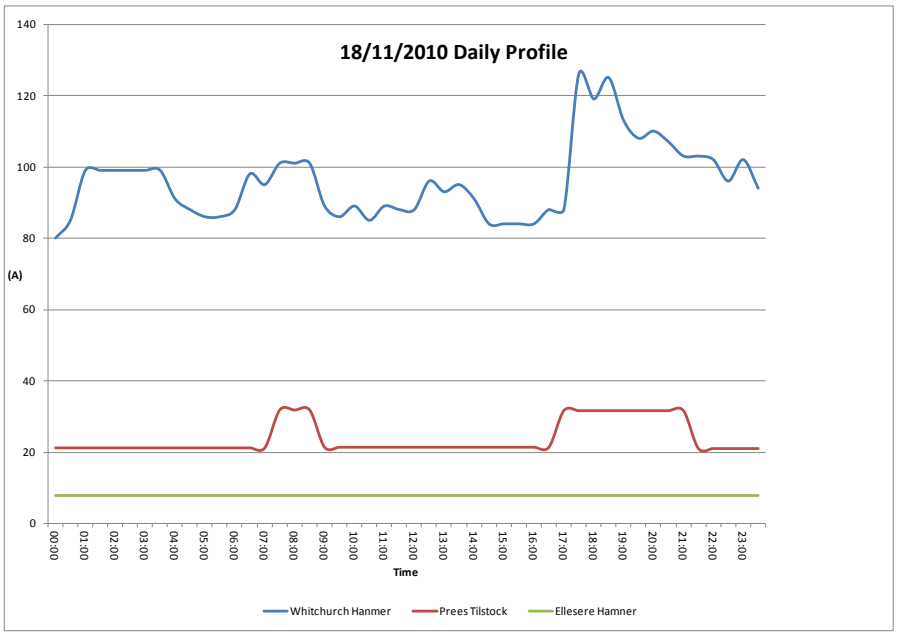
A similar observation occurs when considering the average profile for the month around 19/01/2010 as shown below.



It can be concluded that because the current profiles for interconnecting feeders are similar in magnitude and peak load period, there is limited opportunity for load transfer.

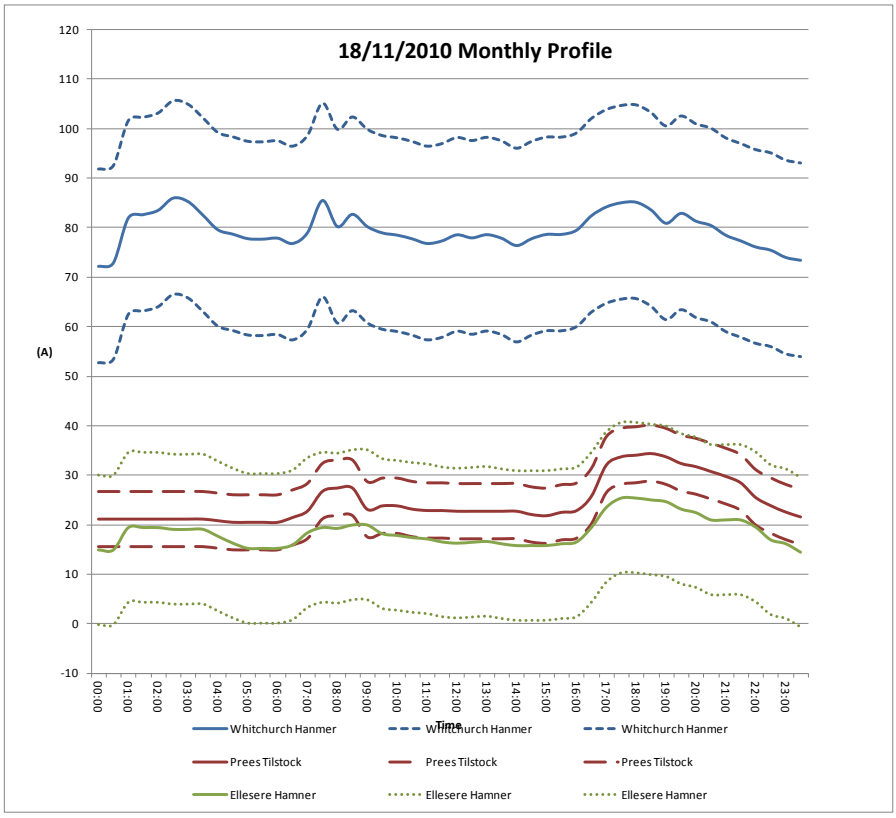
5.3.4 Whitchurch~Hanmer Feeder

The Whitchurch~Hanmer feeder has connectivity to adjacent networks at Prees Tilstock and Ellesmere Hanmer. The maximum instantaneous currents observed on this feeder were on 18/11/2010 and the daily profile is shown in the chart below.



This daily profile shows that there may be potential to transfer load from Whithchurch~Hanmer to either Prees~Tilstock or Ellesmere~Hanmer.

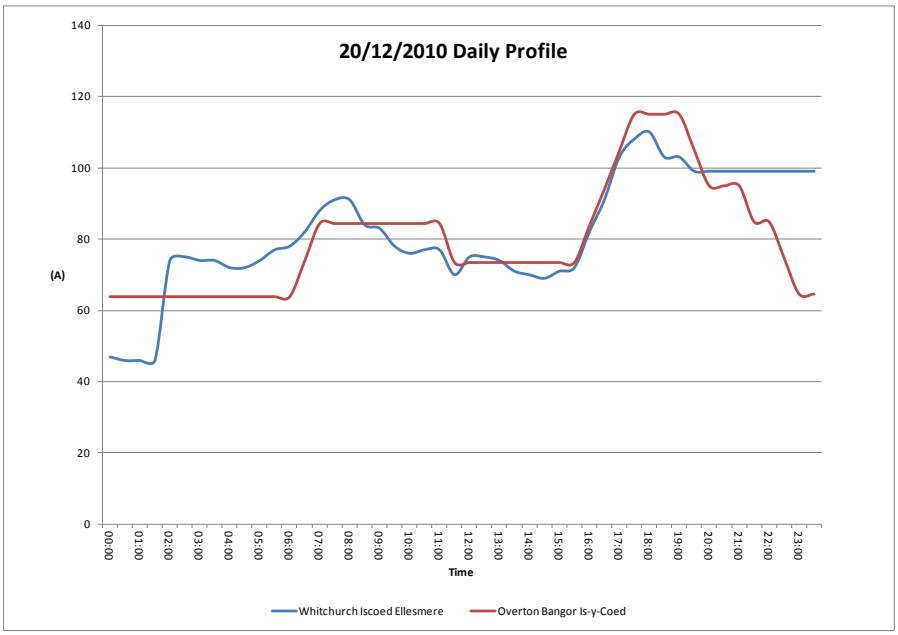
The monthly profile around the maximum current below also shows that some load from Whitchurch Hanmer could be transferred to Prees Tilstock or Ellesmere Hanmer as the peak loading period on the Whitchurch Hanmer feeder does not generally coincide with the time of peak loading on either the Prees~Tilstock or Ellesmere~Hanmer feeders. This may be due to Economy 7 heating on Ellesmere Hanmer.



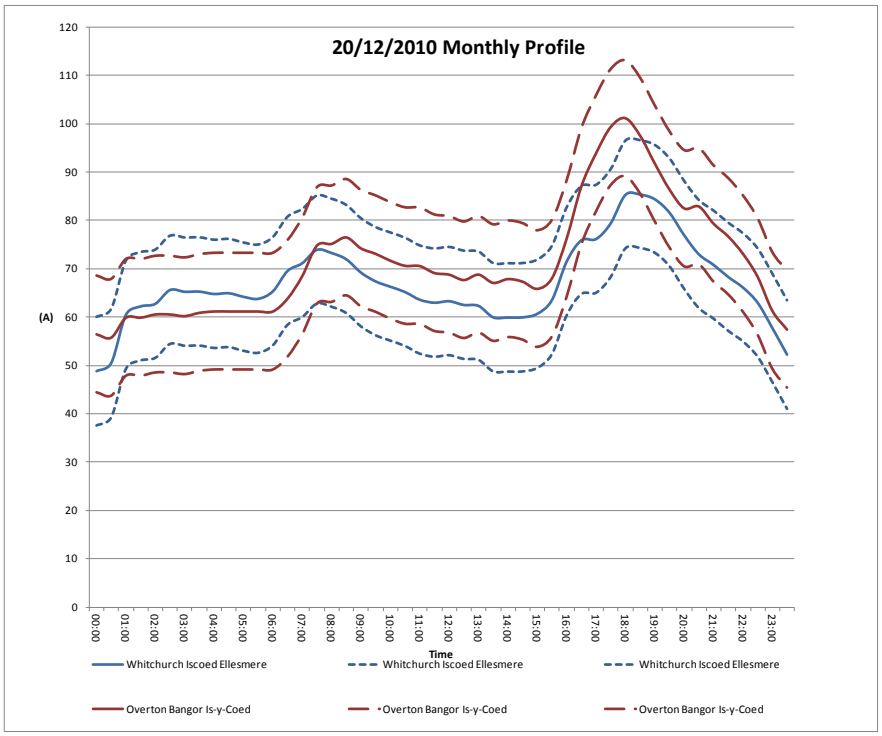
It can be concluded that there may be opportunities for load transfer between Whitchurch~Hanmer and Prees~Tillstock or Ellesmere~Hanmer.

5.3.5 Whitchurch~Iscoed Ellesmere Feeder

The Whitchurch~Iscoed Ellesmere has connectivity with the adjacent Overton~Bangor-Is-Y-Coed feeder. The maximum instantaneous current for the Iscoed feeder was recorded on 20/12/2010 and the daily profile is shown in the figure below.



The daily profile above and the monthly average daily profile shown below for these feeders indicate that there is limited opportunity for load transfer as the load profiles match one another closely and the maximum feeder current on Overton~Bangor-Is-Y-Coed between 2010 and 2012 was 133A which is 70% of rated capacity.



5.4 Recommendations for Load Transfer

The feeder current analysis has considered PI data for the Whitchurch network group and 9 interconnecting feeders from 6 adjacent primary substations from 2010 to 2012. The analysis suggests that key opportunities for load transfer would be;

1. Whitchurch~ Bargates | Liverpool Road~Green End Arcade | Yockings Gate~Talbot St
2. Whitchurch~Hanmer to Ellesmere~Hanmer or Prees Tilstock
3. Whitchurch~Bradley Willey Moor to Wrenbury Frith~Willeymoor
4. Yockings Gate United Dairies to Liverpool Rd Care Home

The fourth opportunity identified is primarily to improve CI and CML and is not assessed in this report.

6 IPSA Modelling and Headroom Assessment

This section describes key findings from the IPSA power flow modelling to assess load transfer opportunities and potential new NCP locations.

6.1 Opportunity 1 - Liverpool Road~Green End Arcade

The feeder currents taken from PI data at timestamp 07/12/2010 10:30 (for maximum instantaneous current on Liverpool Rd~Green End Arcade) were used to establish feeder loading conditions for the IPSA model of the Whitchurch network group during normal conditions.

The N-1 condition for Liverpool Road was considered for analysis. The N-1 condition for Yockings Gate and Whitchurch primary transformers will result in similar feeder loadings but on different feeders however key findings will still be valid.

The figure below shows the circuit configuration including status of NOPs (where a red solid square indicates closure of a NOP) used for analysis of N-1 conditions at Liverpool Road primary substation.

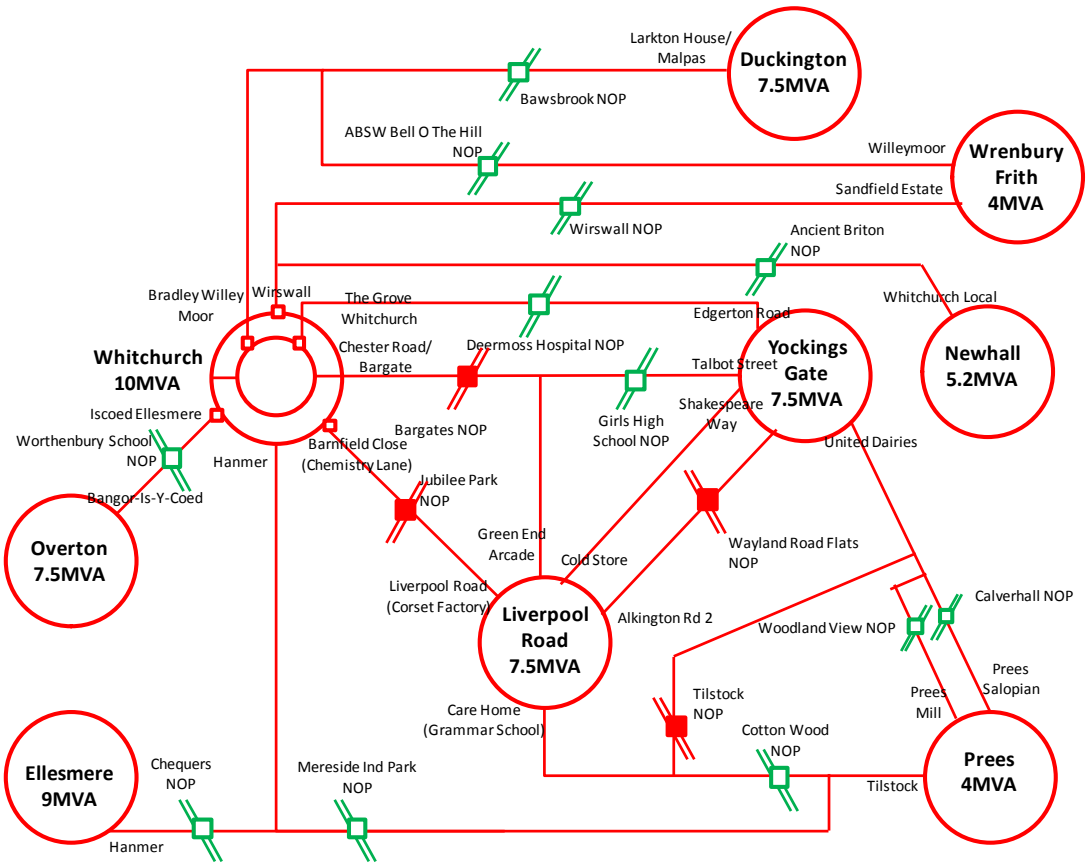


Figure 16 - Opportunity 1, N-1 Liverpool Road

6.1.1 NOP at Bargates

The feeder currents for normal and N-1 conditions for a NOP at Bargates are provided in the table below. This feeder loading is acceptable.

Feeder	PI Feeder Current	IPSA Current	N-1 Liverpool Road IPSA Current
Whitchurch~Chester Road Bargates	8	6	6
Liverpool Road~Green End Arcade	137	138	0
Yockings Gate~Talbot Street	12	13	153

The maximum loading conditions for the Yockings Gate~Talbot Street feeder between 2010 and 2012 under normal conditions was 36A. Load transfer may not be appropriate during high loading of both Yockings Gate~Talbot Street and Liverpool Road~Green End Arcade feeders.

6.1.2 NOP at Girls High School

Alternatively, if Bargates NOP is closed and Girls High School NOP is open, Whitchurch~Chester Rd Bargates feeder picks up 142A.

Feeder	PI Feeder Current	IPSA Current	N-1 Liverpool Road IPSA Current
Whitchurch~Chester Road Bargates	8	6	148
Liverpool Road~Green End Arcade	137	138	0
Yockings Gate~Talbot Street	12	13	13

The maximum loading conditions for the Whitchurch~Chester Road Bargates feeder between 2010 and 2012 under normal conditions was 79A. Load transfer would not be appropriate during high loading of both Whitchurch~Chester Road Bargates and Liverpool Road~Green End Arcade feeders.

6.1.3 NOP at Green End Arcade

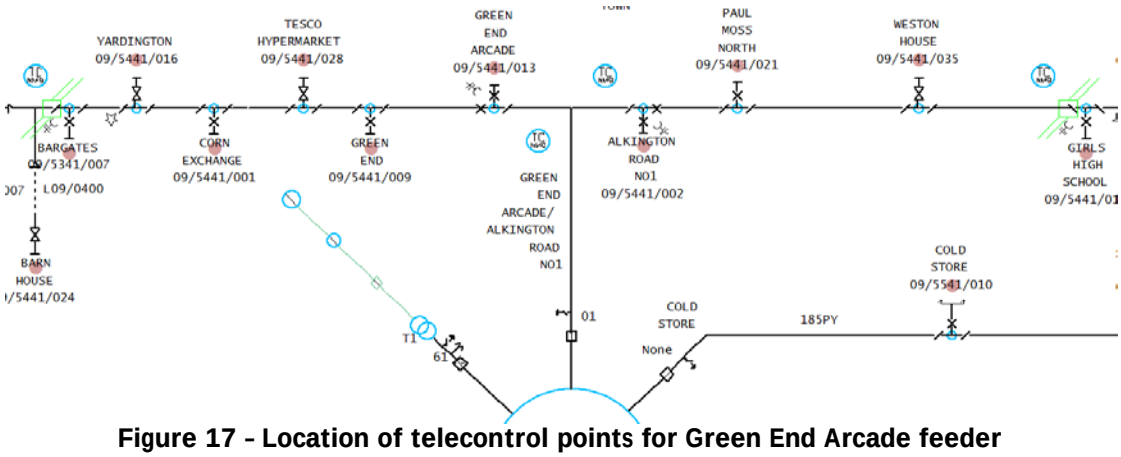


Figure 17 - Location of telecontrol points for Green End Arcade feeder

Two options for load transfer on the Liverpool Road~Green End Arcade feeder are explored based on the existing telecontrol points. These are shown in an excerpt from Poweron in Figure 17.

6.1.4 NCP at Green End Arcade

The feeder currents with the telecontrol point open at Green End Arcade and closed at Bargates and Girls High School are given in the table below. This indicates an improved distribution of load between the Whitchurch~Chester Road Bargates and Yockings Gate~Talbot Street feeders during the N-1 condition.

Feeder	PI Feeder Current	IPSA Current	N-1 Liverpool Road IPSA Current
Whitchurch~Chester Road Bargates	8	6	85
Liverpool Road~Green End Arcade	137	138	0
Yockings Gate~Talbot Street	12	13	75

6.1.5 NCP at Alkington Road No1

The feeder currents with the telecontrol point at Alkington Road No 1 open and Bargates and Girls High School NOPs closed are given in the table below. This gives a similar improvement of load distribution.

Feeder	PI Feeder Current	IPSA Current	N-1 Liverpool Road IPSA Current
Whitchurch~Chester Road Bargates	8	6	75
Liverpool Road~Green End Arcade	137	138	0
Yockings Gate~Talbot Street	12	13	85

6.1.1 Recommendations

It is recommended that the telecontrol points at Green End Arcade and Alkington Rd No 1 are considered for automation for load transfer under N-1 conditions. Load transfer from Liverpool Road to Yockings Gate should improve CI and CML for the Liverpool Road~Green Arcade feeder as well. However, load transfer may not be appropriate during peak loading of both Yockings Gate~Talbot Street and Liverpool Road~Green End Arcade feeders and the lower rated capacity of Yockings Gate should also be considered.

6.2 Opportunity 2 - Whitchurch~Hanmer

The Whitchurch~Hanmer feeder may provide opportunity for load transfer, however when transferring load to Prees primary substation (~9.5km) or Ellesmere primary substation (~15km away), voltage drop may become an issue. There are heavy load centers towards the end of the Whitchurch~Hanmer feeder at Wardle Metals (1.16MVA) and Mereside Industrial Park (Transformer Rating 500kVA), close to the NOP at Mereside Industrial Park.

The feeder currents taken from PI data at timestamp 18/11/2010 17:30 (maximum instantaneous current on Whitchurch~Hanmer) were used to establish feeder loading conditions for the IPSA model of the Whitchurch network group during normal conditions.

6.2.1 Resupply from Ellesmere

Current loading and voltage drop for resupply of the Whitchurch~Hanmer feeder from Ellesmere primary substation during an N-1 at Whitchurch is shown below. In this case, the NOP at Chequers would be closed.

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Max. Voltage Drop
Whitchurch~Hanmer	126	122	0	
Ellesmere~Hanmer	8	8	132	0.97pu

The statutory lower voltage limit for the 11kV network is 0.94pu. Under normal conditions, a voltage drop of 3% would generally be acceptable. However, under N-1 conditions, it is acceptable at SPEN for the voltage drop to more closely approach the limit. The maximum voltage drop is experienced close to the Whitchurch primary substation and is acceptable.

However, the increased thermal loading for the Ellesmere~Hanmer feeder may potentially impact headroom for Ellesmere primary substation particularly if outage conditions occur during peak loading at both Whitchurch and Ellesmere primaries. The maximum loading conditions for the Ellesmere~Hanmer feeder between 2010 and 2012 was 104A and under this condition, load transfer would exceed cable rating.

This resupply configuration has been used previously during N-1 conditions for Whitchurch primary.

6.2.2 Resupply from Prees

Current loading and voltage drop for resupply of the Whitchurch~Hanmer feeder from Prees primary substation during an N-1 at Whitchurch is shown below.

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Max. Voltage Drop
Whitchurch~Hanmer	126	122	0	
Prees~Tilstock	32	35	172	0.88pu

The maximum voltage drop is experienced close to the Whitchurch primary substation and is outside statutory voltage limits. Therefore, it would not be

feasible to resupply Whitchurch~Hanmer from Prees~Tilstock during N-1 conditions at Whitchurch.

6.2.3 Resupply from Liverpool Road

Under N-1 at Whitchurch (loss of Whitchurch primary transformer), the Chester Road Bargates feeder can be used to maintain supply to both Whitchurch~Hanmer and Whitchurch~Iscoed Ellesmere feeders from Liverpool Road primary substation.

The feeder loading for this configuration was assessed along with potential additional NCPs to reduce feeder loading. The telecontrol point at Alkington Road was used to reduce the current on the Liverpool Road~Green End Arcade feeder. The figure below shows the circuit configuration including status of NOPs. It was assumed that Whitchurch~Iscoed Ellesmere is resupplied from Overton in this case.

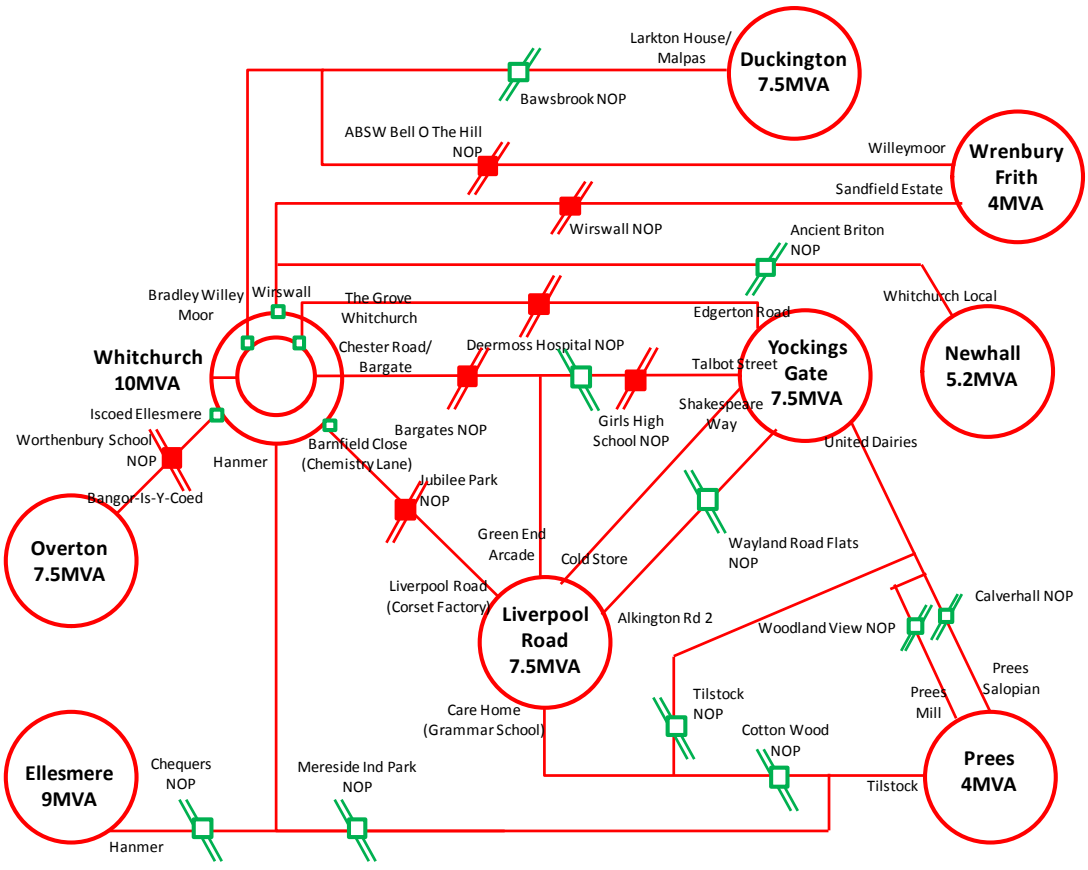


Figure 18 - Opportunity 2, N-1 Whitchurch

Current loading and voltage drop for resupply of the Whitchurch~Hanmer feeder from Liverpool Road primary substation during an N-1 at Whitchurch is shown below.

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Min. Voltage
Whitchurch~Hanmer	126	128	0	
Ellesmere~Hanmer	8	8	8	
Liverpool Rd~Green End Arcade	103	101	207	0.93pu

The maximum voltage drop of 0.93pu is experienced at the end of the Whitchurch~Hanmer feeder at Mereside Industrial Park and is close to statutory voltage limits. Also, the current exceeds the feeder capacity of 189A.

6.2.3.1 NCP near Firbend

Load transfer to the Ellesmere~Hanmer feeder by adding a NCP between Chequers NOP and Whitchurch primary could reduce the voltage drop experienced and provide a more flexible configuration. This is explored below.

Feeder	N-1 Whitchurch IPSA Current	Min. Voltage
Ellesmere~Hanmer	92	0.98pu
Liverpool Rd~Green End Arcade	120	0.98pu

The maximum loading conditions for the Ellesmere~Hanmer feeder between 2010 and 2012 was 104A and under this condition, load transfer would exceed cable rating.

6.2.3.2 NCP near Wardle Metals

Load transfer to the Prees~Tilstock feeder by adding a NCP between Wardle Metals and The Conery could provide similar benefits however voltage drop is excessive as shown below. There is an existing telecontrol point between Wardle Metals and Chequers NOP at Bowkers Lane. As Wardle Metals is a HV customer, there is the possibility of managing the voltage drop with a voltage regulator if required.

Feeder	N-1 Whitchurch IPSA Current	Min. Voltage
Prees~Tilstock	115	0.92pu
Liverpool Rd~Green End Arcade	126	0.97pu

For a NCP between Wardle Metals and Mereside Industrial Park, voltage drop and thermal loading is given below. Thermal loading of the Liverpool Rd~Green End Arcade feeder is too high in this case.

Feeder	N-1 Whitchurch IPSA Current	Min. Voltage
Prees~Tilstock	47	0.99pu
Liverpool Rd~Green End Arcade	193	0.94pu

6.2.4 Recommendations

It is recommended that a NCP is installed near Firbend secondary substation to enable a flexible configuration and resupply from both Liverpool Road primary and Ellesmere primary under N-1 conditions at Whitchurch, as required. This will depend on the loading conditions on the Ellesmere~Hanmer and Liverpool Rd~Green End Arcade feeders at any given time. However, permanent load transfer to Ellesmere~Hanmer is not recommended given the existing headroom at Ellesmere primary. It is not possible to transfer load to Prees due to potential voltage drop and thermal capacity issues.

6.3 Opportunity 3 - Whitchurch~Bradley Willey Moor

The Whitchurch~Bradley Willey Moor feeder may provide opportunity for load transfer, however when transferring load to Wrenbury Frith primary substation (~7.5km) or Duckington primary substation (~9.5km), voltage drop may become an issue due to circuit length.

Also, Duckington and Wrenbury Frith are fed from the 132kV Cheshire network and there may be issues with voltage phase angle difference during switching. However, this could potentially be managed as required by operations.

The feeder currents taken from PI data at timestamp 07/12/2010 18:00 (maximum instantaneous current on Whitchurch~Bradley Willey Moor) were used to establish feeder loading conditions for the IPSA model of the Whitchurch network group during normal conditions.

Load transfer opportunities for Whitchurch~Bradley Willey Moor to Wrenbury Frith~Willeymoor are also assessed backfeeding through The Grove feeder from Yockings Gate primary substation.

6.3.1 Resupply from Wrenbury Frith

Current loading and voltage drop for resupply of the Whitchurch~Bradley Willey Moor feeder from Wrenbury Frith primary substation during an N-1 at Whitchurch is shown below. In this case, the NOP at Bell O the Hill would be closed.

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Min. Voltage
Whitchurch~Bradley Willey Moor	56	57	0	
Wrenbury Frith~Willey Moor	3	3	61	0.96pu

The maximum voltage drop is experienced close to Bawsbrook NOP and is acceptable. This resupply configuration has been used previously during N-1 conditions for Whitchurch primary. The maximum loading conditions for the Wrenbury Frith~Willey Moor feeder between 2010 and 2012 was 45A. Even under maximum loading conditions on the Wrenbury Frith~Willey Moor feeder, this load transfer is suitable.

Wrenbury Frith primary substation has 25% theoretical available headroom and the load transfer is unlikely to reduce this significantly.

6.3.2 Resupply from Duckington

Current loading and voltage drop for resupply of the Whitchurch~Bradley Willey Moor feeder from Duckington primary substation during an N-1 at Whitchurch is shown below. In this case, the NOP at Bawsbrook would be closed.

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Min. Voltage
Whitchurch~Bradley Willey Moor	56	57	0	
Duckington~Larkton House	85	84	143	0.93pu

The maximum voltage drop is experienced close to the Whitchurch primary substation and at the end of one of the Whitchurch~Bradley Willey Moor spurs and is excessive. This is due to impedance of the long rural overhead lines.

6.3.3 Resupply from Yockings Gate

Under N-1 at Whitchurch (loss of Whitchurch primary transformer), the Grove feeder can be used to maintain supply to both Whitchurch~Bradley Willey Moor and Whitchurch~Wirswall feeders from Yockings Gate primary substation through Yockings Gate~Edgerton Road.

The feeder loading for this configuration was assessed along with potential additional NCPs to reduce feeder loading. Figure 10 shows the circuit configuration including status of NOPs, the Deermoss Hospital NOP would be closed in this scenario. It was assumed that Whitchurch~Wirswall feeder is resupplied from Newhall or Wrenbury Frith in this case.

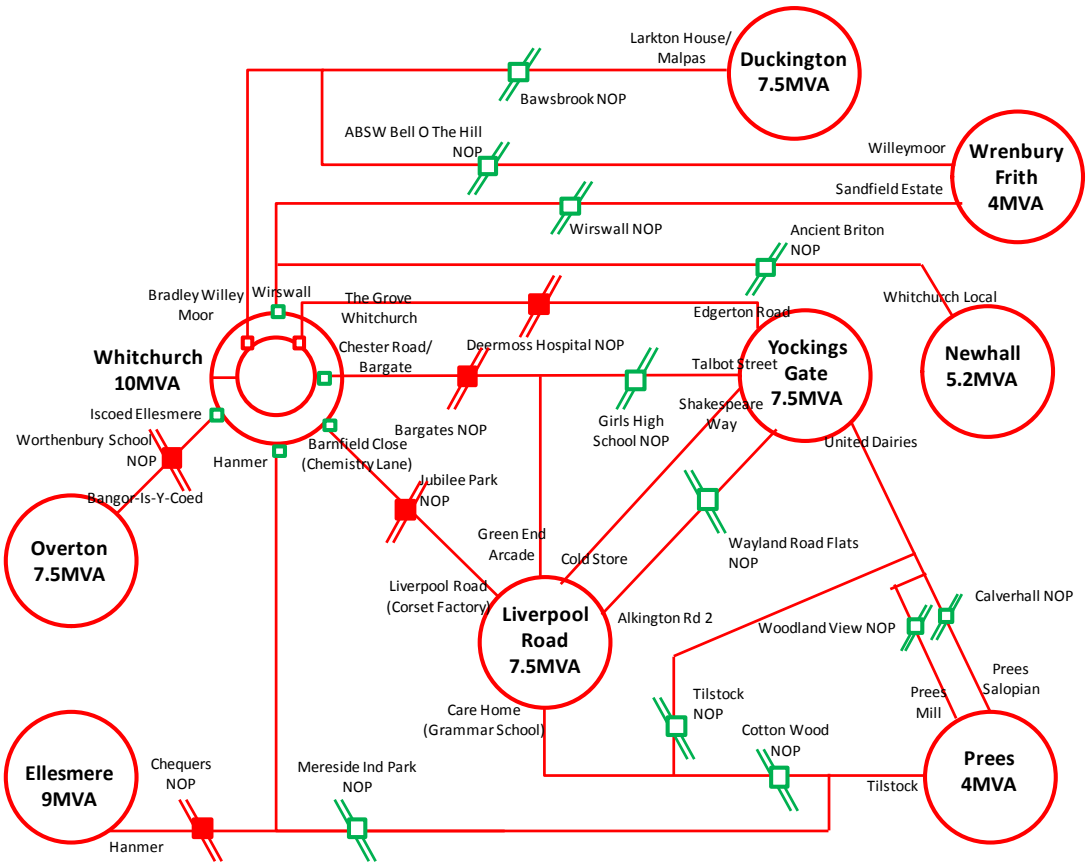


Figure 19 - Opportunity 3, N-1 Whitchurch

Feeder	PI Feeder Current	IPSA Current	N-1 Whitchurch IPSA Current	Min. Voltage
Whitchurch~Bradley Willey Moor	56	57	0	
Yockings Gate~Edgerton Road	47	48	117	0.96pu

The maximum voltage drop is experienced at the end of one of the Whitchurch~Bradley Willey Moor spurs and is acceptable.

The maximum loading conditions for the Yockings Gate~Edgerton Road feeder between 2010 and 2012 was 64A. Even under maximum loading conditions on the Yockings Gate~Edgerton Road feeder, this load transfer is suitable and thus, from this analysis, there are no recommendations for additional NCPs on the Whitchurch~Bradley Willey Moor feeder.

6.3.4 Recommendations

A temporary or permanent load transfer to the Wrenbury Frith feeder is a potential alternative network configuration to enable improvement in headroom in the Whitchurch network group as well as a limited reduction of loading of the Whitchurch 33kV network (up to 1.1MVA). Implications for CIs, CMLs and voltage phase angle difference may require further consideration for any load transfer. The circuit is predominantly overhead line.

There are no recommendations for additional NCPs on the Whitchurch~Bradley Willey Moor feeder.

6.4 Benchmark Network Headroom

Network headroom was calculated for the current network configuration for various N-1 conditions. The timestamp for the maximum aggregate primary substation loading in 2012 (14.06MVA) was used as the basis of individual transformer and feeder loadings under normal conditions. These were scaled to be as representative as possible to PI data for maximum loading conditions.

Network headroom was calculated for the Whitchurch network group below. This shows the distribution of load between the various primaries. Headroom is calculated on the basis of primary transformer rating for individual transformers (7.5 MVA, 10 MVA) and for the network group firm capacity (20 MVA) for the total headroom.

Table 3 – Primary transformer and network headroom for various loading conditions

Loading condition	Yockings Gate (MVA)	Yockings Gate Headroom	Liverpool Road (MVA)	Liverpool Road Headroom	Whitchurch (MVA)	Whitchurch Headroom	Total (MVA)	Total Headroom	Minimum Voltage (pu)
Normal	3.72		4.47		5.87		14.06		
N-1 Yockings Gate - A			7.64	-1.9%	6.80	32.0%	14.44	27.8%	0.90 (United Dairies)
N-1 Yockings Gate - B			5.87	21.7%	6.80	32.0%	12.68	36.6%	0.82 (United Dairies)
N-1 Liverpool Road - C	8.21	-9.5%			6.20	38.0%	14.41	28.0%	0.93 (United Dairies)
N-1 Liverpool Road - D	6.37	15.1%			8.03	19.7%	14.40	28.0%	0.94 (United Dairies)
N-1 Liverpool Road - E	6.06	19.2%			8.03	19.7%	14.09	29.6%	0.96 (United Dairies)
N-1 Whitchurch – F	5.68	24.2%	9.04	-20.5%			14.74	26.3%	0.95 (Mereside Ind Park)
N-1 Whitchurch – G	3.91	47.9%	5.87	21.7%			9.78	51.1%	0.97 (Mereside Ind Park)

The status of the NOPs for each loading condition are described below;

A. Close Deermoss Hospital, Girls High School, Wayland Rd Flats and Tilstock NOPs

B. Close Deermoss Hospital, Girls High School, Wayland Rd Flats and Calverhall (United Dairies) NOPs

C. Close Girls High school, Jubilee Park, Wayland Rd Flats, Tilstock and Shakepeare Way

D. Close Bargates, Jubilee Park, Wayland Rd Flats, Tilstock and Shakepeare Way

E. Close Bargates, Jubilee Park, Wayland Rd Flats, Cotton Wood and Shakepeare Way NOPs, Open Tilstock NOP

F. Close Bargates, Deermoss Hospital and Jubilee Park NOPs

G. Close Bargates, Deermoss Hospital and Jubilee Park, Open all circuit breakers at Whitchurch primary substation

A diagram of the network group NOPs is given below for clarity.

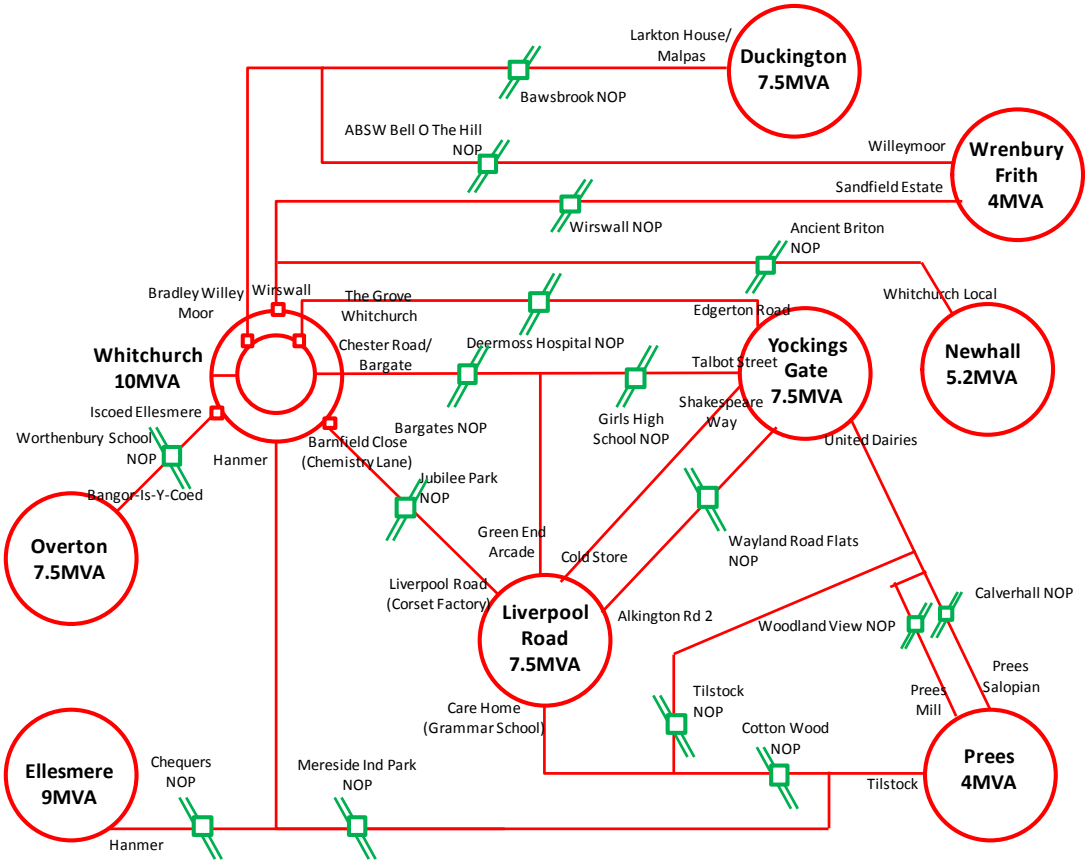


Figure 20 – 11kV Whitchurch network group and adjacent networks

Headroom is increased if load is transferred out of the network group however, under high loading conditions, this may lead to substantial voltage drop on the interconnecting feeder in the adjacent network due to circuit length as for loading condition B. This has been explored in detail to develop the proposed new configuration.

6.5 Network Headroom with Proposed New Configuration

The network headroom was calculated for the proposed new network configuration for various N-1 conditions. The same loading conditions were used as for the network headroom benchmark study.

The proposed new configuration is based on the addition of telecontrol points at;

- Green End Arcade
- Alkington Rd No 1
- Firbend
- Tilstock Car Sales

The percentage of capacity headroom release is shown for each telecontrol point although it should be noted that this only applies for particular N-1 conditions.

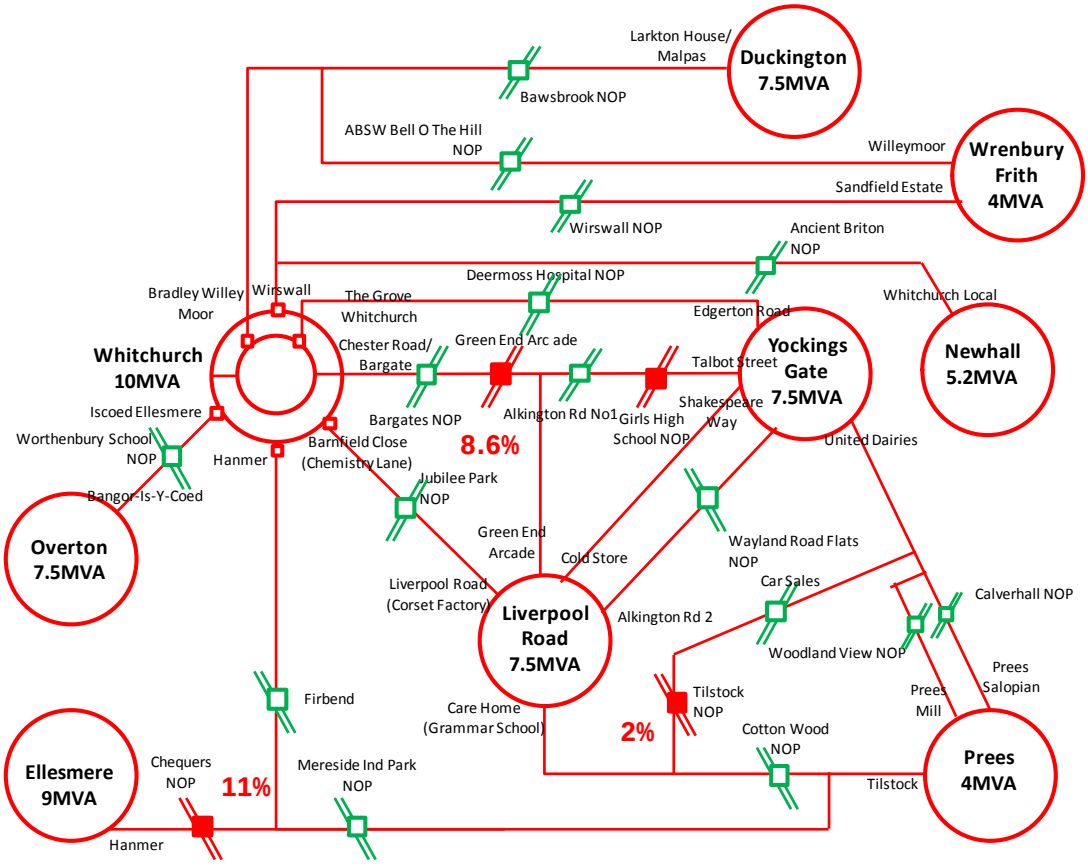


Figure 21 – Proposed new Whitchurch network group configuration

Table 4 – Primary transformer and network headroom for various loading conditions for proposed new network configuration

Loading condition	Yockings Gate (MVA)	Yockings Gate Headroom	Liverpool Road (MVA)	Liverpool Road Headroom	Whitchurch (MVA)	Whitchurch Headroom	Total (MVA)	Total Headroom	Minimum Voltage (pu)
Normal	3.72		4.47		5.87		14.06		
N-1 Yockings Gate - A			6.40	14.7%	6.41	35.9%	12.81	36.0%	0.91 (United Dairies)
N-1 Yockings Gate - B			4.67	37.3%	6.41	35.9%	11.08	44.6%	0.83 (United Dairies)
N-1 Liverpool Road - C	6.96	7.2%			5.81	41.9%	11.93	40.4%	0.93 (United Dairies)
N-1 Liverpool Road - D	6.38	14.9%			6.41	35.9%	11.94	40.3%	0.94 (United Dairies)
N-1 Liverpool Road – E	5.75	23.3%			6.41	35.9%	11.31	43.5%	0.95 (United Dairies)
N-1 Whitchurch – F	4.86	35.2%	7.15	4.7%			12.01	40.0%	0.98 (Wirswall)
N-1 Whitchurch - F	3.91	47.9%	5.87	21.7%			9.78	51.1%	0.97 (Mereside Ind Park)

The status of the NOPs for each loading condition are described below;

A. Close Deermoss Hospital, Girls High School, Wayland Rd Flats, Tilstock and Bargates NOPs, Open Green End Arcade NCP

B. Close Deermoss Hospital, Girls High School, Wayland Rd Flats, Bargates and Calverhall (United Dairies) NOPs, Open Green End Arcade NCP

C. Close Girls High school, Jubilee Park, Wayland Rd Flats, Tilstock, Shakepeare Way and Bargates NOPs, Open Green End Arcade NCP

D. Close Bargates, Jubilee Park, Wayland Rd Flats, Tilstock and Shakepeare Way NOPs

E. Close Bargates, Jubilee Park, Wayland Rd Flats, Tilstock and Shakepeare Way NOPs, Cotton Wood NOP and open NCP near Tilstock Car sales

F. Close Bargates, Deermoss Hospital and Jubilee Park NOPs

G. Close Bargates, Deermoss Hospital and Jubilee Park, Open all circuit breakers at Whitchurch primary substation

These are comparable to the network configurations under N-1 for the current network to enable evaluation of headroom improvement. Configuration E did not appear to result in any voltage drop issues for the Prees network.

6.5.1 Improvement in Headroom

Improvement in headroom was assessed for each primary transformer and for the network group by evaluating the reduction in MVA and improvement in headroom for each network configuration during an outage (loading condition). Headroom is calculated on the basis of primary transformer rating for individual transformers (7.5 MVA, 10 MVA) and for the network group firm capacity (20 MVA) for the network group headroom. For example, for the Whitchurch group, the benchmark headroom is based on an existing loading of 14.44MVA in the current configuration during N-1 conditions compared to the firm N-1 capacity of 20MVA. Similarly, for the loading under the proposed new configuration. The improvement, or reduction, in load is calculated from loading in the proposed new configuration compared to loading in the existing configuration, percentage improvement is then the load improvement in MVA divided by the existing loading in the current configuration (1.63/14.44 for the Whitchurch network group).

This assumes that the percentage improvement in loading is retained as load growth rises across the Whitchurch network group in the future. In reality, it is likely to be clustered in various locations potentially resulting in variation of network group loading improvement.

Loading for the proposed and existing configuration is based on the worst-case loading condition presented in Tables 4 and 5. If an alternative network configuration with improved headroom could be used for this loading condition, then the assessment was based on the best viable network configuration. This includes consideration of the minimum voltage experienced during N-1 conditions.

Table 5 – Improvement in primary transformer and network headroom for worst-case loading conditions

Loading condition	Yockings Gate	Liverpool Road	Whitchurch		Whitchurch Network Group
Current configuration (MVA)	6.06	7.64	8.03		14.44
Benchmark Headroom (%)	**19.2%**	**-1.9%**	**19.7%**		**27.8%**
Proposed new configuration (MVA)	5.75	6.4	6.41		12.81
New Headroom (%)	**23.2%**	**14.7%**	**35.9%**		**36.0%**
Improvement (MVA)	0.31	1.24	1.62		1.63
Improvement (%)	**4%**	**16%**	**20%**		**11%**

It can be seen that in the current network configuration, Yockings Gate and Whitchurch primary transformers are the highest loaded under the worst case N-1 condition which is the loss of the Liverpool Road primary transformer. Network configuration E provides the most headroom under this outage.

With the proposed new network configuration, it should be possible to add up to approximately 4% or more to Yockings Gate primary transformer headroom. The other primary transformers have higher headroom gains. Up to **11%** in gain may be possible for the Whitchurch network group headroom.

15 Conclusions

Based on analysis of the Whitchurch network group and interconnecting feeders to adjacent network groups, it is recommended that the following telecontrol points are considered for load transfer during N-1 conditions;

- Green End Arcade
- Alkington Rd No 1

It is also recommended that a NCP is installed near Firbend secondary substation to enable a more flexible configuration. This will depend on the loading conditions on the Ellesmere~Hanmer and Liverpool Rd~Green End Arcade at any given time. Permanent load transfer to Ellesmere~Hanmer is not recommended given the existing headroom at Ellesmere primary.

A temporary or permanent load transfer to the Wrenbury Frith feeder may be considered to enable improvement in headroom in the Whitchurch network group as well as a limited reduction of loading of the Whitchurch 33kV network. Impact on CIs, CMLs and voltage phase angle difference require further consideration though.

A NCP should also be installed near Tilstock Car Sales on the Yockings Gate~United Dairies feeder to enable load transfer to the Tilstock feeder on the Prees network during loss of the Liverpool Road primary transformer.

With the proposed new network configuration, it should be possible to add up to approximately 4% or more to the Yockings Gate primary transformer headroom. The other primary transformers have higher headroom gains. Up to **11%** in gain may be possible for the Whitchurch network group headroom.

The next stage in the project is a review of existing control equipment and assessment and refinement of new NCP locations including in terms of impact on CI/CMLs and practicalities.

Some further data collection and analysis has also been identified that can contribute to understanding the dynamic behaviour of Whitchurch network group and potential for load transfer. This is described below;

- Unbalance on the OH networks to assess opportunities to balance the system and thus improve efficiency and explore the accuracy of current loading data used for system analysis.
- A data trawl will be required of the RTU type installed at NCP locations for suitability of recovering loading data from the Whitchurch network group and adjacent networks. If key nodes are of the first generation RTU, the RMU+, then recommendations may include upgrading. There may also be nodes on this network where additional RTUs could be installed purely for load data recovery, where there may be suitable switchgear already installed

- Identify POC locations for HV Customers/Large LV Customers for consideration of using portable equipment to confirm phase balance and loading against capacity.

It should be possible to include this within the existing scope.