Trial Substation Selection Methodology

CLASS Project

LCN Fund
Low Carbon Networks

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CONTENTS

VERSION HISTORY

Version	Date	Author	Status (draft, etc)	Comments
v1	30 August 2013	Electricity North West	1st Issue	1st Issue

GLOSSARY OF TERMS

Abbreviation	Term
ASC	Autonomous Substation Controller
AVC	Automatic Voltage Control
CLASS	Customer Load Active System Services
GSP	Grid Supply Point
HV	High Voltage
Ofgem	Office of the Gas and Electricity Markets
PC	Profile Class
PLS	Peak Load Share
SDRC	Successful Delivery Reward Criteria
TCMK	Transformer Compound Marshalling Kiosk

All other definitions shown starting with a Capital letter are as per LCN Fund Governance Document v6.

1   EXECUTIVE SUMMARY

The Ofgem Project Direction issued on 21[St] December 2012 outlines certain Successful Delivery Reward Criteria (SDRC), against which the success of the Customer Load Active System Services (CLASS) project will be assessed. For each criterion, the Project Direction defines the evidence that is required to demonstrate successful delivery.

There are seven discrete SDRC evidence required for the Technology Build Workstream of the CLASS project (as per the list below).

This report is one of two[1] documents to deliver evidence 2 on the list.

1. Publish the design of the regulation scheme for substation Voltage Controllers by February 2014
2. ***Publish the site selection report including the methodology by August 2013***
3. Network monitoring equipment installed and commissioned by March 2014
4. Publish the commissioning reports by April 2014
5. Technology go-live by April 2014
6. ICCP installed and commissioned by March 2014
7. Publish the ICCP commissioning reports by April 2014

This report describes the methodology for the selection of primary substations for the CLASS trial, and the outcomes from its application.

The selection of primary substations for the CLASS trial was undertaken in three main stages; initial screening, classification and final selection.

Initial screening excluded unsuitable primary substations according to the following criteria:

- **System configuration** – to exclude primaries operating in parallel, single transformer primaries and primary transformers with unequal ratings.
- **Planned system works** – where outages could affect the trial programme.

The classification stage involved assessment and ranking of all primaries. This was based on demand zone, load level, load class, generation level and practical appropriateness.

Using this approach, 65 primary substations were selected. This included five reserve primaries, one of which (Levenshulme) was used. At least two primaries were selected from each Grid Supply Point group. The loading at the majority of selected primaries was greater than 75% of the firm capacity and 17 sites have been selected with a Load Index of five, ie the present or forecast loading is expected to exceed 100% of the primary firm capacity.

The final selection is representative of the Electricity North West network and provides confidence that the learning from the trial could be applied to other distribution networks.

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[1] This report should be read in conjunction with the *CLASS Monitoring Location Report*, which together with this document delivers evidence 2 above.

2 INTRODUCTION

The Customer Load Active System Services (CLASS) project is funded via Ofgem's Low Carbon Networks (LCN) second tier funding mechanism. Electricity North West received formal notification of selection for funding on 21 December 2012. The project is due for completion by 30 September 2015.

CLASS is investigating how reactive power flow and demand response change when voltage is varied through primary transformer taps. It is assessing opportunities for:-

i. reducing network peak demand and so defer network reinforcement
ii. providing frequency control though demand response
iii. managing National Grid network voltages through reactive power absorption

Extensive CLASS trials are planned to assess the relationship between voltage and demand. During these trials, tap positions of parallel primary transformers will be changed simultaneously and staggered to observe the response of loads at different times of the day and throughout the annual load cycle. Trial results will enable the evaluation of the application of the CLASS principles.

This report describes the methodology used to select the primary substations for the CLASS trials and the outcomes from applying this methodology.

The circuit selection methodology has been developed to ensure that the final selection of trial sites covers the geographic area covered by the Electricity North West distribution system and includes a representative range of customer types. Therefore, it is anticipated that the trial results will be applicable to the whole Electricity North West network and could be extrapolated to reflect other distribution networks.

3   DESCRIPTION OF CIRCUIT SELECTION METHODOLOGY

The steps of the circuit selection methodology are shown below in Figure **1**.

Each of these steps is described in more detail in the sections of this report that follow.

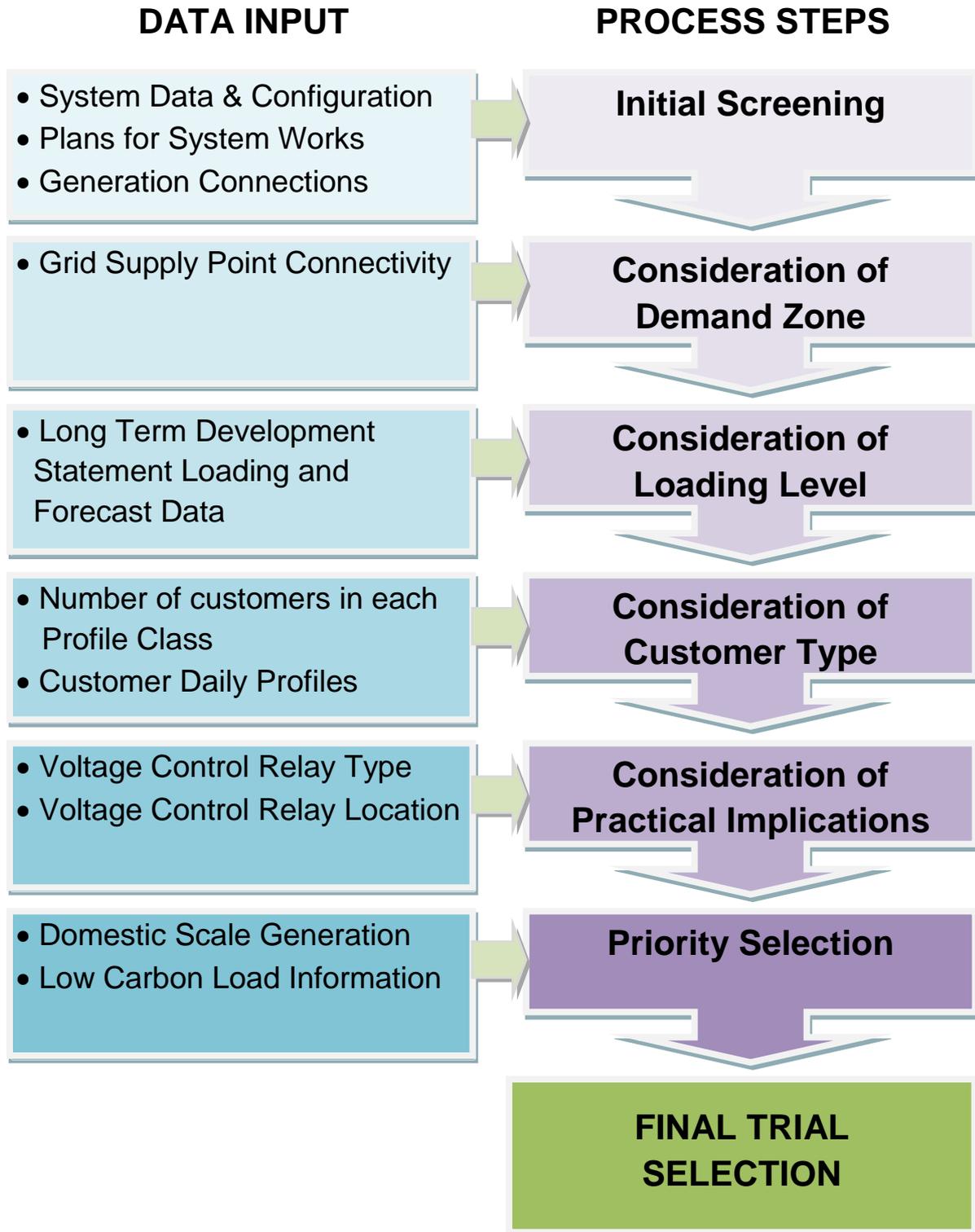| DATA INPUT	PROCESS STEPS
• System Data & Configuration • Plans for System Works • Generation Connections	**Initial Screening**
• Grid Supply Point Connectivity	**Consideration of Demand Zone**
• Long Term Development Statement Loading and Forecast Data	**Consideration of Loading Level**
• Number of customers in each Profile Class • Customer Daily Profiles	**Consideration of Customer Type**
• Voltage Control Relay Type • Voltage Control Relay Location	**Consideration of Practical Implications**
• Domestic Scale Generation • Low Carbon Load Information	**Priority Selection**
	FINAL TRIAL SELECTION

Figure 1 : CLASS Trial primary substation selection methodology.

4 INITIAL SCREENING

Initial screening was applied to the total population of approximately 360 primary substations within the Electricity North West network to avoid locations where the system configuration or system operation could affect the implementation of the trial or the trial results. The criteria below were used to exclude primaries from the selection list:

- System configuration – Interconnection, single transformer and mismatch
- System works
- HV connected distributed generation

4.1 System Configuration

4.1.1 Single Transformer Sites
The CLASS trial will investigate the demand response to transformer tap changes, tap stagger and when one of a pair of parallel transformers is switched out. Consequently, single transformer primaries were excluded from the list, as these would not be appropriate for the full range of CLASS trial.

During initial screening, 54 primary substations were therefore excluded due to being single transformer sites or operating as such.

4.1.2 Parallel Primaries
Primaries which run in parallel with other primaries via either 11kV or 6.6kV connections were excluded. The CLASS trials will involve fitting a voltage controller at each primary and as such, split site operations would be inappropriate.

Primaries which normally operate with the bus-section open were also excluded as it would not be possible to conduct the full range of CLASS trial tests at these sites.

A further 11 sites were therefore excluded due to normally operating with the bus-section open.

4.1.3 Unequal Primary Transformer Ratings
Primaries where the ratings of the parallel transformers are substantially unequal, and therefore possibly have unequal impedances also, were excluded from the selection. This was to avoid any problems with unequal sharing of the power flows when the smallest transformer could be a limiting factor reducing the application of the trial.

During initial screening, 19 primary substations were identified as having mismatched transformers and were therefore excluded from the selection. However two primaries with slight ONAN rating differences were selected. These were Blackpool which had an ONAN rating of 15MVA on T11 with 16MVA on T12 and Westgate with 20MVA on T11 and 11.5MVA on T12. These two sites were chosen to be representative of the wider primary substation population with mismatched rating transformers but similar impedance values.

4.2 Planned System Works

Primaries where outages are expected in order to accommodate works planned during the trial period were excluded to ensure that the CLASS trial programme was not adversely

affected. Sites where Electricity North West is planning to install HV reactive compensation (fixed capacitors) during the trial period were also excluded to avoid any programme clashes and to avoid any changes in reactive power demand complicating the trial results.

41 projects are scheduled to be undertaken by Electricity North West during the period January 2014 to September 2015, and are likely to include planned outages of primary transformers.

Based on these planned projects, four primary substations were excluded from the selection.

4.3   Distributed Generation Connected to the HV Network

One of the objectives of the CLASS trial is to evaluate the relationship between demand and voltage changes. Significant amounts of embedded generation could alter the observed response, resulting in the specific response of load types being masked. Consequently, primaries with HV connected generation corresponding to more than 50% of the maximum demand were generally excluded from the selection. To enable the project to assess what effect embedded generation has on applicability of the CLASS techniques, a site (Trafford Park North Primary) with significant embedded generation has been retained and included in the selection.

Real power ratings of the generators connected at HV were obtained for each primary substation in February 2013, from the database of all embedded generation maintained by Electricity North West. These values were calculated as percentages of the 2011/12 maximum demand for each primary as listed in the Electricity North West Long Term Development Statement. 18 primary substations were noted to have HV generator connections of more than 50%.

As indicated above, Trafford Park North Primary where the HV connected generation is greater than 50% of the maximum demand, has been included in the selection to enable learning.

5   CLASSIFICATION

5.1   Demand Zone

Electricity North West's distribution system covers a wide range of area; from scarcely populated regions in Cumbria to urban areas within and surrounding cities such as Manchester, with high concentrations of commercial, industrial and domestic customers. It was considered important that the selected primaries reflected the whole Electricity North West region, and hence all customer types, to maximise the learning outcomes of the trial and ensure the transferability to other UK distribution networks. Consequently, the methodology included consideration of the Grid Supply Point groups, ensuring selection of primaries in all such groups.

Grid Supply Points are the interface between the transmission system (normally 400kV or 275kV) and the distribution network (normally at 132kV). The Electricity North West network is connected to the National Grid's transmission system at 17 Grid Supply Points, listed in Table 1, located across the whole geographic area.

Selecting primaries from each of the Grid Supply Point groups has the benefit that the effects of the trialled techniques will be measured at all of Electricity North West's Grid interfaces.

Table 1: Electricity North West Grid Supply Points.

BOLD	KEARSLEY	SOUTH MANCHESTER
BREDBURY	MACCLESFIELD	STALYBRIDGE
CARRINGTON	PADIHAM	STANAH
HARKER	PENWORTHAM EAST	WASHWAY FARM
HEYSHAM	PENWORTHAM WEST	WHITEGATE
HUTTON	ROCHDALE	

5.2   Load Level

One of the objectives of the CLASS trial is to investigate the use of demand response, initiated through active voltage management to defer network reinforcement. Consequently, primary substations with the greatest loadings were selected for the trial because it was considered that these were where this benefit, i.e. network reinforcement deferral, was most likely to be of relevance.

Maximum load values for the year 2011/2012 for each primary were obtained from Electricity North West's 2012 Long Term Development Statement, along with load forecast values for 2016/2017. The average of these two values for each primary was used to identify the primaries with the greatest loading and to rank them for selection.

The loading value for approximately 10% of primaries was found to be greater or equal to 95% and the loading of approximately 45% of primaries were found to be greater or equal to 75%.

5.3   Customer Type

Static loads (often constant impedance) and motors are known to respond differently to changes in supply voltage. Consequently, it is expected that the demand by different customer types will respond differently to voltage changes, due to the variances in static and motor load types making up the load of different customer types.

Customer types have been considered as part of the trial selection methodology to ensure that learning is obtained on how demand from these different customer types responds to the CLASS techniques.

Electricity North West maintains a record of the numbers of customers connected to each primary by Profile Classes, as shown in Table 2 below.

Table 2: Profile Classes.

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

Customer numbers are not considered to be a good reflection of the division of the load fed from a primary substation because the consumption of an individual domestic customer is normally much less than that of an individual non-domestic customer. Consequently a methodology based upon power share was used to categorise the type of customer supplied by each Primary. This "Peak Load Share" methodology was utilised during the selection of primaries for the CLASS trial at the bid stage. The methodology is depicted in Figure 2.
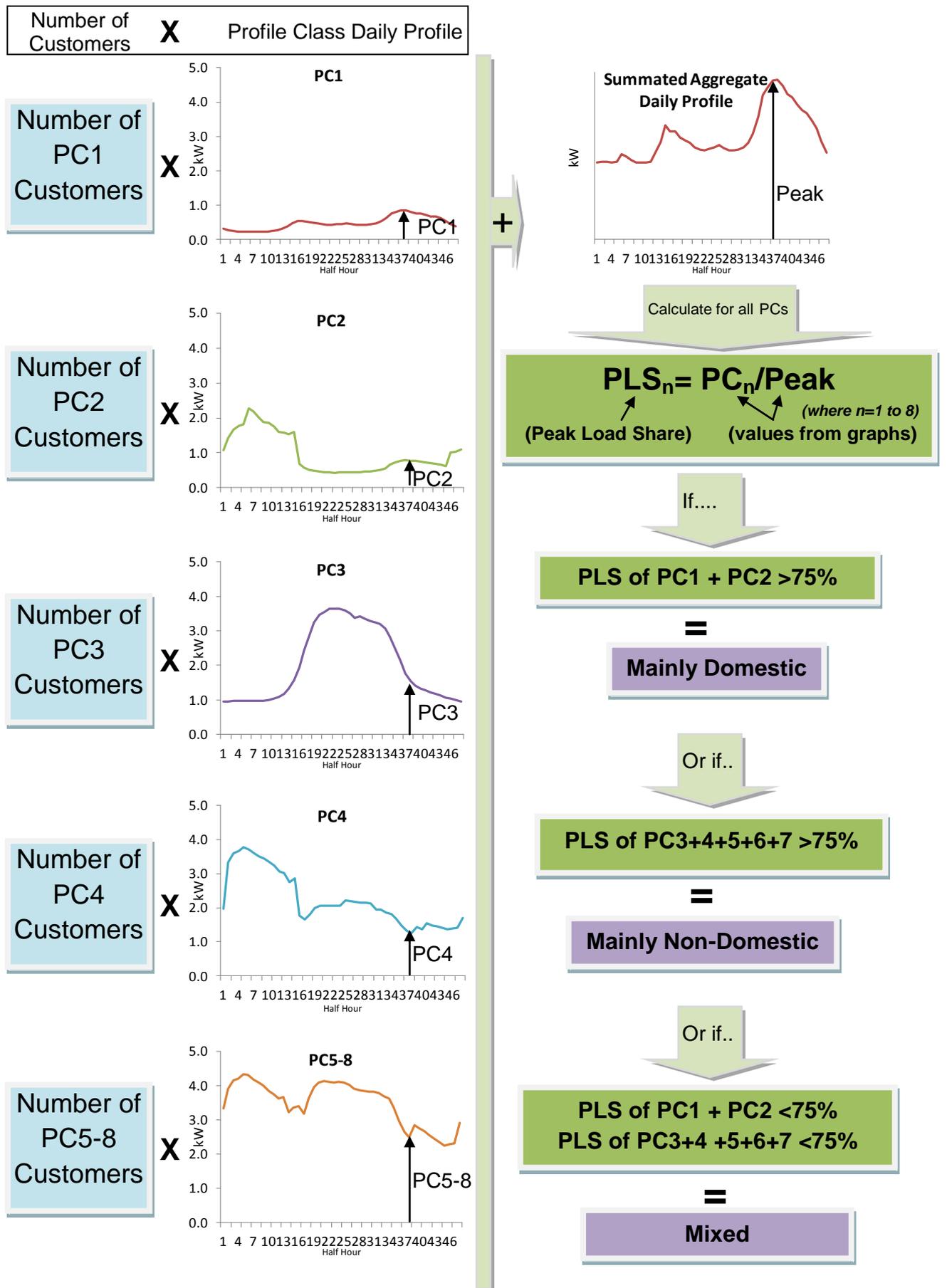
Figure 2: "Peak Load Share" methodology.

Standard daily profiles were obtained for a range of customer Common Distribution Charging (CDCM) Methodology tariff types. These were assumed to correspond to Profile Classes as shown in Table 3 below.

An aggregate daily profile for each primary was calculated by summing these standard daily profiles for each profile class multiplied by the relevant number of each type of customer.

The aggregate daily profile was not expected to replicate the actual daily profile of the primary demand. It is simply an approximation for the sole purpose of identifying the percentage of the peak demand consumed by customers in each Profile Class. The primary's daily peak demand and its time of occurrence were identified using the aggregate profile. Peak Load Share for each Profile Class was then calculated by dividing the demand of all customers in the Profile Class at the time of the aggregate peak by the aggregate peak demand. The overall customer type was determined using the resultant percentages based on the definitions given in Table 4.

Table 3: CDCM Tariff Daily Profiles assumed to correspond to each Profile Class.

Profile Class	Assumed Corresponding CDCM Tariff Daily Profile
PC1	Domestic Unrestricted
PC2	Domestic Two-Rate
PC3	Small Non-Domestic Unrestricted
PC4	50% Small Non-Domestic Off-Peak 50% Small Non-Domestic Two-Rate
PC5 to PC8	LV Medium Non-Domestic

Table 4: CDCM Tariff Daily Profiles assumed to correspond to each Profile Class.

Load Classification	Peak Load Share
Mainly Domestic	Summed Peak Load Share of PC1 and PC2 >75%
Mainly Non-Domestic	Summed Peak Load Share of PC3 through to PC8 >75%
Mixed	Summed Peak Load Share of PC1 and PC2 <75% Summed Peak Load Share of PC3 through to PC8 <75%

6   CONSIDERATION OF PRACTICAL IMPLICATIONS

Modifications to the existing wiring of primary transformer Automatic Voltage Control (AVC) relays will be required to accommodate the control functionality necessary for the CLASS trials.

Modification of indoor modern AVC relays is expected to be the simplest and quickest type of legacy to MicroTAPP AVC conversion process. However, it is anticipated that the nature of other legacy AVC installations may mean that the necessary changes to accommodate the CLASS trials are either impossible, high risk, difficult or significantly time consuming. AVC relays installed outdoors present significant risks to project completion, due to the uncertainty over suitable spare secondary/control wiring cores to the Transformer Compound Marshalling Kiosk, TCMK. Furthermore delays may be encountered during possible outdoor civil works, e.g. laying new multi-cores underground.

Some existing AVC installations utilise legacy AVC relays, which will not have appropriate fibre optic communications inputs, e.g. the AVE, AVE3, AVE5 and Brush Star. These are likely to be less able to accommodate the modifications required for the CLASS trial and therefore it may be necessary to either change the legacy AVC relays for modern versions or to fit interposing relays.

The definitions of the categories assigned to the AVC installation at each Primary are given below in Table 5.

Table 5 : AVC Installation Categories.

Category	Description
Category A	Indoor Micro TAPP (modern) AVC Relays
Category B	Indoor Brush Star (legacy) AVC Relays or mixed Super TAPP/Micro TAPP with AVE/Brush Star (legacy) AVC Relays
Category C	Outdoor Micro TAPP (modern) AVC Relays
Category D	Indoor AVE/Brush Star AVC (legacy) Relays
Category E	Outdoor AVE/Brush Star (legacy) AVC Relays
Category X	Uncertain AVC relay type and/or relay location

Category A primaries were considered in the selection due to them being indoor modern relays and thus presenting least project risk. Category B and D primaries were also considered within the selection since the additional risk of the legacy relays was judged to be acceptable. However, sites with modern relays were chosen in preference when possible.

Primaries categorised as C and E were excluded from the list being considered for selection due to the aforementioned issues with outdoor installations. However, one primary (Longsight) categorised as E was included in the selection to enable assessment of the installation of the Autonomous Substation Controller (ASC) at a site with an existing outdoor AVC scheme.

Primaries included in the selection and categorised initially as X (uncertain relay type or location) were surveyed. They were to be substituted with primaries from the reserve list

should the survey results indicate that they are unsuitable for the CLASS trial however they proved to be suitable for Type 1 (Carr St) and Type 4 (Annie Pit) installations

7   PRIORITY SELECTION

7.1   Low Carbon Technologies

Load composition could change as low carbon technologies (LCTs) become more prevalent. It is the intention that the CLASS trials recognise this evolution and so consider the response of loads best reflecting the future load composition.

Specific data regarding plans, for connections of developments making extensive use of low carbon technologies, e.g. vehicle charging locations and heat pumps, have been difficult to obtain. As a broad and wide-ranging set of Primary substations have been selected for the trials, these are likely to cover areas where connection of LCTs is most likely. In particular, the selected sites include urban areas where electric charging is most probable, as well as suburban areas where new apartment or commercial buildings using heat pump technology are expected to be developed.

7.2   Embedded Small Scale Generation

Low carbon initiatives are resulting in increasing numbers of domestic scale generators, particularly photovoltaic panels, being connected to the electrical distribution system. It is important that the CLASS trial also investigate the effect that these have on the applicability of the CLASS techniques.

The average capacity of small scale embedded generator connections corresponds to approximately 1.6% of the maximum demand at each Primary. We have checked that the ratings of Low Voltage connected small scale generators, at each of the primaries included in the selection, is near to the overall average. Within the selection of 60 primaries, 17 have above average Low Voltage connected small scale generation. There are three primaries with above 4% small scale embedded generation.

8   SELECTION RESULTS

A detailed list of the primary substations selected for the CLASS trial can be found in Appendix A.

A total of 65 Primaries have been selected, including five on a reserve list as a contingency should on site practicalities prevent the installation of the necessary equipment.

At least one primary has been selected from each of the Grid Supply Point group.

All selected primaries are loaded to more than 75% of the firm capacity.   Seventeen primaries have been selected with a Load Index of 5, i.e. the present or forecast loading is expected to exceed 100% of the Primary firm capacity.

The selection includes Primaries with a representative mix of customer types, as shown in Figure 3.
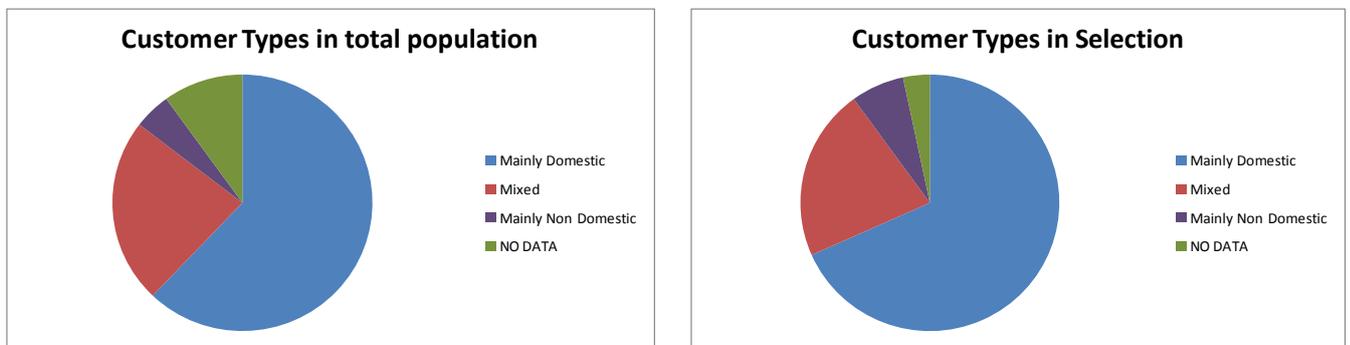

Figure 3: Comparison of Customer Types in whole Electricity North West population and CLASS trial selection.

The primaries selected for the CLASS trial are judged to be representative of the range of Primaries within the total Electricity North West circuit population. This is illustrated in the following figures.
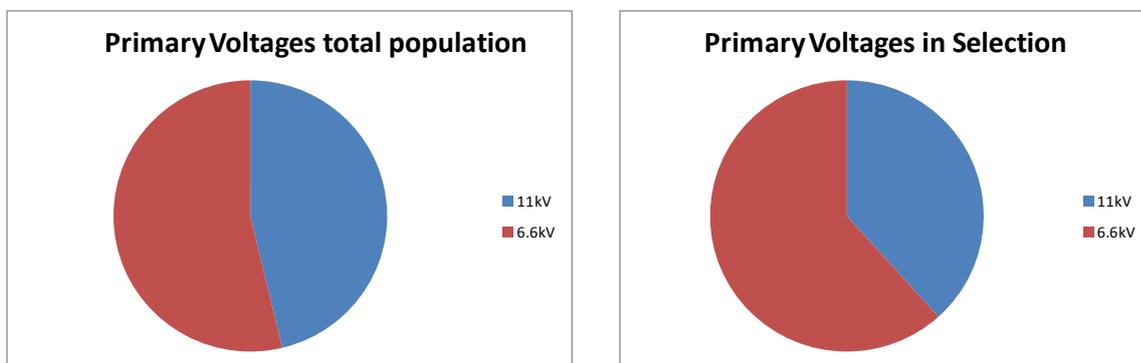

Figure 4: Comparison of Primary voltages in the whole Electricity North West population and CLASS trial selection.
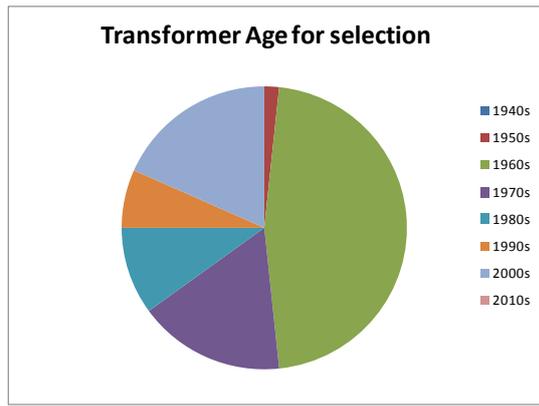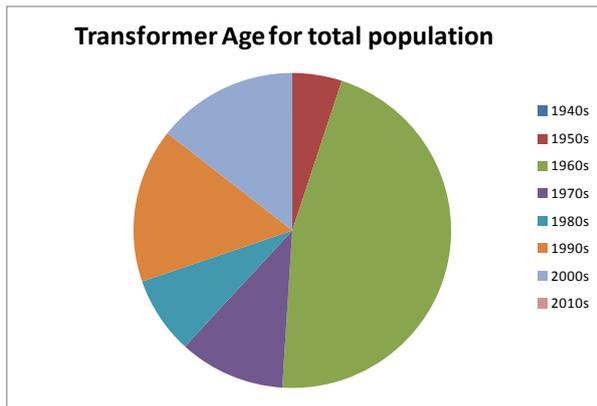
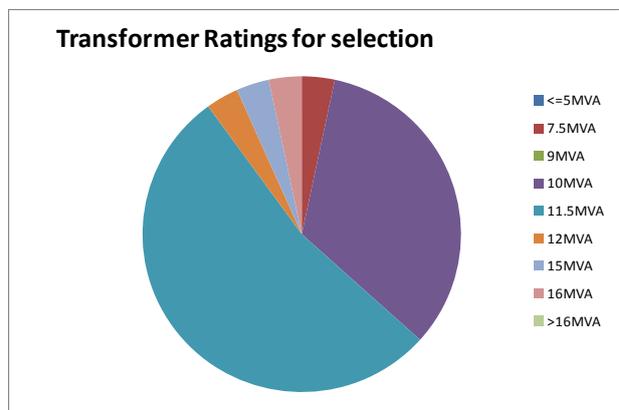**Figure 5:** Comparison of transformer ages in the whole Electricity North West population and CLASS trial selection.
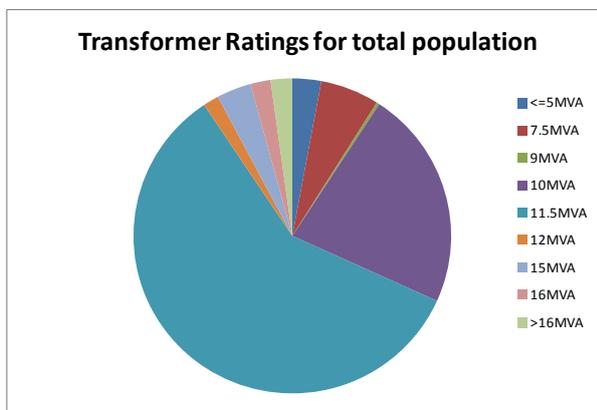

Figure 6: Comparison of transformer ratings in the whole Electricity North West population and CLASS trial selection.

APPENDIX A – PRIMARY SUBSTATION CLASS TRIAL SELECTION MAIN LIST

Grid Supply Point	BSP	Primary
BOLD	Golborne	ASHTON-Golborne
		GOLBORNE
BREDBURY	Adswood	WINIFRED RD
	Longsight	FALLOWFIELD
		LONGSIGHT
		MOSS SIDE (Longsight)
		VICTORIA PARK
		LEVENSHULME
	Vernon Park	ROMILEY
CARRINGTON	Altrincham	GREEN LANE-Altrincham
	Barton	CHASSEN RD
		TRAFFORD PARK NORTH
	Carrington	IRLAM
	Sale	BAGULEY
HARKER/ HUTTON	Egremont	EGREMONT
	Penrith/Shap	KIRKBY STEPHEN
	Stainburn	ANNIE PIT
	Barrow	CHATSWORTH ST
HEYSHAM	Lancaster	BURROW BECK
		WESTGATE
KEARSLEY	Bolton	HARWOOD
	Bury	CHAMBERHALL
	Frederick Road	BLACKFRIARS
		TRINITY
	Westhoughton	LOSTOCK
KEARSLEY LOCAL	Kearsley (local)	CARR ST
		CAMPBELL ST
MACCLESFIELD	Macclesfield	BOLLINGTON
		S.W. MACCLESFIELD
PENWORTHAM EAST/ ROCHDALE SGT 1	Preston East	AVENHAM
	Ribble	DOUGLAS ST
		BAMBER BRIDGE
	Lower Darwin	GRIFFIN
PENWORTHAM WEST/ STANNAH	Wrightington	TARLETON
		CLEVELEYS
	Bispham	BLACKPOOL
	Blackpool	CECIL
	Leyland	BUCKSHAW
ROCHDALE/ PADIHAM	Belfield	LITTLEBOROUGH
		KINGSWAY
	Castleton	HEADY HILL
	Huncoat	HYNDBURN RD
SOUTH MANCHESTER	Bloom Street	BRIDGEWATER
		DICKINSON ST
	Moss Nook	WILMSLOW

Grid Supply Point	BSP	Primary
	West Didsbury	DIDSBURY
		WITHINGTON
STALYBRIDGE	Droylsden	DENTON EAST
		DROYLSDEN EAST
		OPENSHAW
	Hyde	HYDE
	New Mills	GOWHOLE
	Stuart Street	STUART ST
		CENTRAL MANCHESTER
WASHWAY FARM	Skelmersdale	SKELMERSDALE
	Wigan	KITT GREEN
		UPHOLLAND
WHITEGATE	Chadderton	MIDDLETON JUNCTION
	Greenhill	BELGRAVE
	Royton	WILLOWBANK

PRIMARY SUBSTATION CLASS TRIAL SELECTION RESERVE LIST

Grid Supply Point	BSP	Primary
BREDBURY	Longsight	LEVENSHULME
		MANCHESTER UNIVERSITY
HARKER	Carlisle	FUSEHILL
KEARSLEY	Kearsley Local	LITTLE HULTON
STANNAH	Blackpool	SHANNON ST