Designing a Transparent Load Forecasting Methodology

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Abstract

This paper explains how Powerco have transformed a load forecasting technique, limited by legacy data issues, by designing a consistent and repeatable process that is underpinned by a solid methodology, enables continuous improvement and that produces a transparent result able to support detailed review of the methodology and data used to produce each substation forecast.

The legacy load forecast methodology involved rebuilding a six year data set annually, producing a regression trend based on the historical data, and then completing an engineering adjustment to reflect "real world" expectations to produce a substation load growth rate. This approach had a heavy dependence on the quality of our historical load data. As a result, each forecast required a degree of manual intervention that in some cases disconnected the statistical analysis from the engineering understanding of load and network developments. This combined with the other specific issues below ultimately would make it difficult to defend the load forecast results under scrutiny:

- Permanent load transfers were not allowed for in the dataset, resulting in false declining load trends;
- Load forecast was not informed by economic drivers and known customer load changes;
- Load forecast results lacked traceability to historical data and too much flexibility was allowed in engineering adjustment.

The premise for a new load forecasting technique was to demonstrate that the analysis allowed for some clearly supported but consistent engineering control points in the formula and produce a standardised output for easy incorporation into analysis and planning documents. A summary of all data sources, growth factors and engineering control points is produced for each substation load forecast, providing a robust and transparent report for detailed review. In addition, Powerco was able to incorporate industry best practice regionalised econometric data from NZIER and introduce continuous improvement to the process to ensure the forecasting technique will always stay fresh and evolve to meet the organisation's needs.

Powerco has designed a methodology that produces a consistent, defensible and repeatable load forecast, combined with a transparent documentation of the data sources, growth factors and engineering control points applied to the forecast that is sufficient to withstand robust review. A consistent and repeatable load forecast is essential for determining the optimum network developments required to securely supply customer demand into the future, and to allow electricity distribution businesses to invest with confidence.

Issues with the legacy load forecasting methodology

Powerco's legacy load forecasting methodology involved rebuilding a six year historical data set of substation loads annually, requiring a repeated data cleansing effort. Statistical analysis was applied to produce a linear regression trend to derive a load growth rate for each substation. Following this the forecast was moderated by an engineering assessment, intended to screen the linear regression results and adjust for known "real world" expectations related to network developments, to produce a substation load growth rate. The legacy load forecast approach had a heavy dependence on the quality of our historical load data, with consequential issues for accuracy, as shown in Figure 1. As a result, each forecast required a degree of manual intervention that in some cases disconnected the statistical analysis from the engineering understanding of load and network developments.

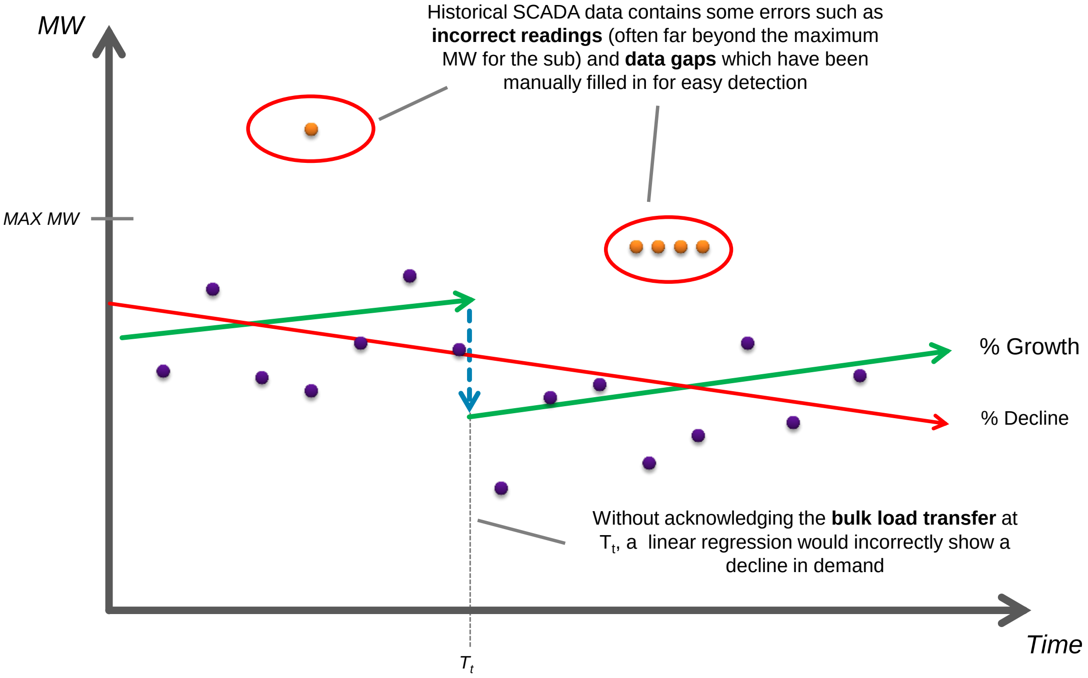


Figure 1 – The trouble with historical data – gaps, incorrect data, outliers and load transfers

Other specific issues with the methodology are:

- Permanent load transfers were not allowed for in the dataset, resulting in false declining load trends from the linear regression. These had to be corrected by engineering adjustment.
- Load forecast was not informed by economic drivers, and so was based on the premise that historical trends would continue into the future. Known customer load changes were not explicitly incorporated, making the forecast agnostic to predicted or committed new loads. In the case of industrial processing loads, these can be substantial and material to network development planning.
- Load forecast results lacked traceability to historical data and too much flexibility was allowed in engineering adjustment.

As a result of these issues, it was difficult to defend the load forecast results under scrutiny, and improvement of the load forecasting methodology was clearly required.

New load forecasting methodology

The premise for a new load forecasting technique was to demonstrate that the analysis allowed for some clearly supported but consistent engineering control points in the formula and produce a standardised output for easy incorporation into analysis and planning documents.

Key improvements were made to provide traceability to historical data, with annual data sources imported into the load forecasting tool for checking and data cleansing, then retained for future load forecasts. After the first year, data additions are for the immediate past year only. To identify a stable peak to model from and to avoid relying on a single peak half hour demand, the average of the 30 highest peaks is obtained to produce the percentage load growth historical trend from linear regression, as shown in Figure 2.

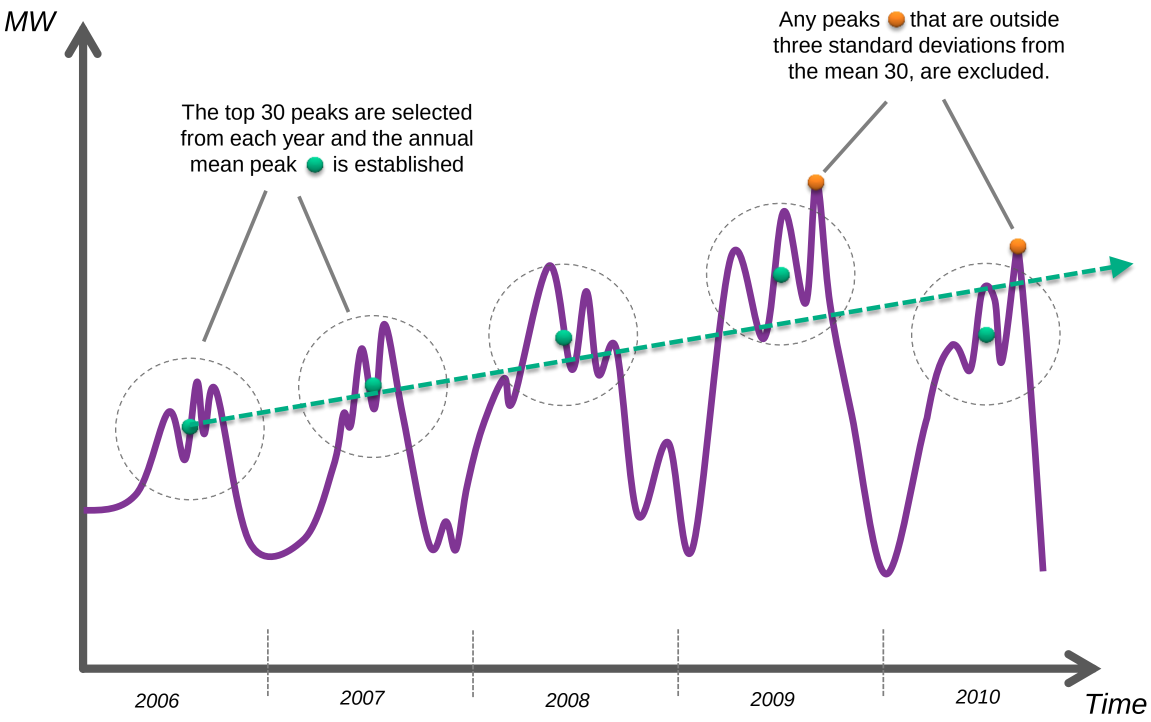


Figure 2 - Daily maximum demand across a number of years and how a mean annual max is derived

Note: 30 peaks are selected (Approximately 8% of the total daily peaks in a year) to give a statistically viable sample

The forecasting tool provides a statistical degree of fit for each annual dataset, providing the engineer with assistance to identify and exclude outliers.

Permanent load transfers can also be allowed for via engineering decisions to determine what years to use in the forecast. Refer to Figure 3a and 3b.

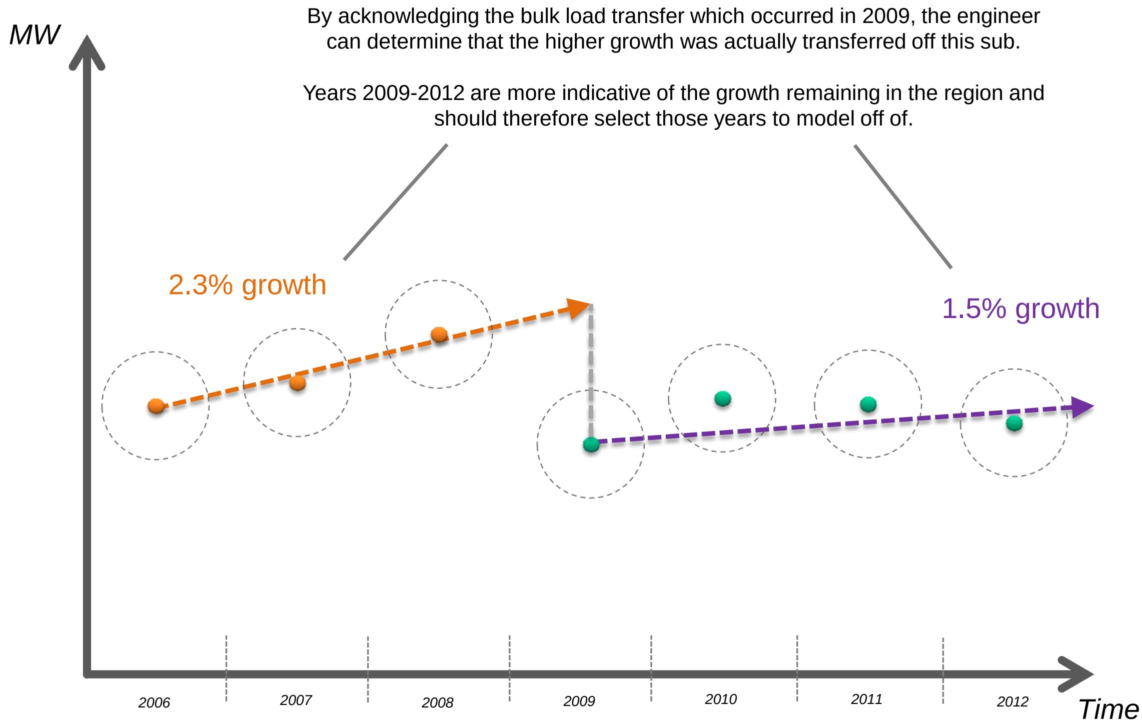


Figure 3a – Mean peak demand across a number of years and how blocks are selected on either side of a bulk load transfer

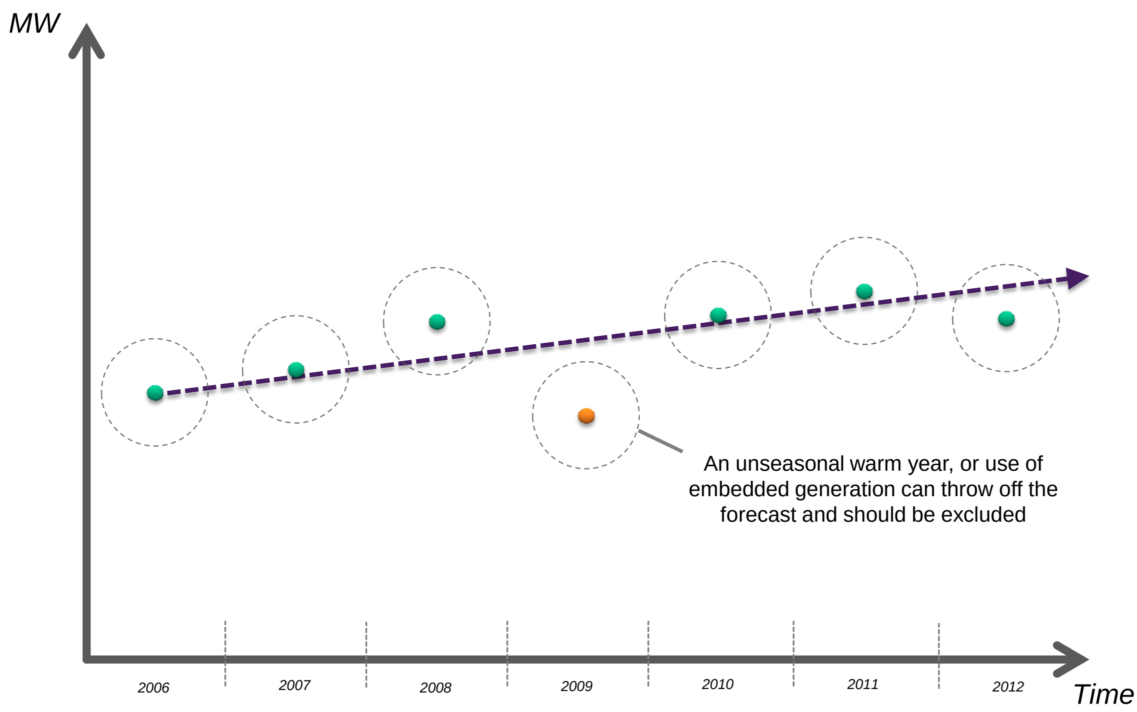


Figure 3b – Mean peak demand across a number years and how individual years are excluded.

Engineering control points were introduced in the load forecast formula to balance three inputs that influence the load growth rate:

1. Historical trend obtained as described above
2. Economic load growth forecasts by customer type
3. Known customer load changes

The load forecast formula is shown in Figure 4 below, showing the engineering control points that can be tuned to obtain the load growth forecast.

Control Point 2- The engineer trade-off between historical and economic forecasts based on the degree of confidence in historical data

Note: $\alpha_1 + \alpha_2 = 1$

$$\textbf{Load}_{t+1} = [\alpha_1(\text{Historical Trend}) + \alpha_2(\text{Economic Forecast})] \times \text{Mean Peak Demand}_t + \text{Bulk Load Changes}_{t+1}$$

Control Point 1 - The engineer can select which years are used to determine the historical trend (%)

Control Point 3 – The engineer can add know step changes in load (MW) at any known point in the forecast

Figure 4 - The load forecast formula

*Note: **Historical Trend** is the forecasted growth rate (%) derived from selected years of historical data, **Economic Forecast** is the forecasted growth rate (%) derived from regionalised econometric data of the proportional industry ICPs on that particular sub and **Bulk Load Changes** are known customer or network driven permanent load transfers in period t+1*

Industry best practice econometric data was obtained on a regional basis from NZIER [1], to produce a future forecast of economic growth related to a number of industry sectors. The long term network demand growth potential is forecast based on production activity (loosely GDP) and household numbers. The NZIER forecasts are influenced by expectations of national and regional trends, such as:

- Slower trend economic growth from population aging and weak labour force growth, sluggish productivity growth
- Declining household size causing faster growth in the number of households compared to population growth
- Expansion of service sectors and contraction of manufacturing as a share of economic activity
- Urbanisation, with major centres increasing their share of the national population

The forecast long term growth for areas within Powerco's networks over 30 years is shown in Figure 5 [1].

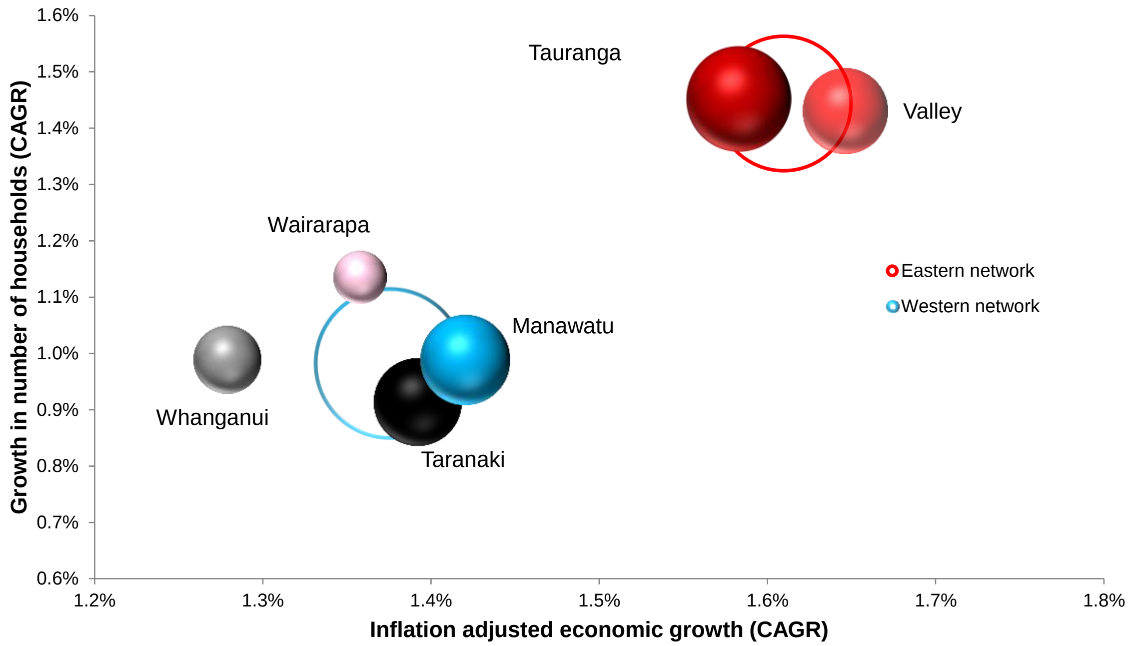


Figure 5: NZIER forecast for household and economic growth

To minimise the uncertainty in the growth projections over the longer term, the growth figures are based on the economic and geographic trends that are the most predictable and stable due to path dependency, such as:

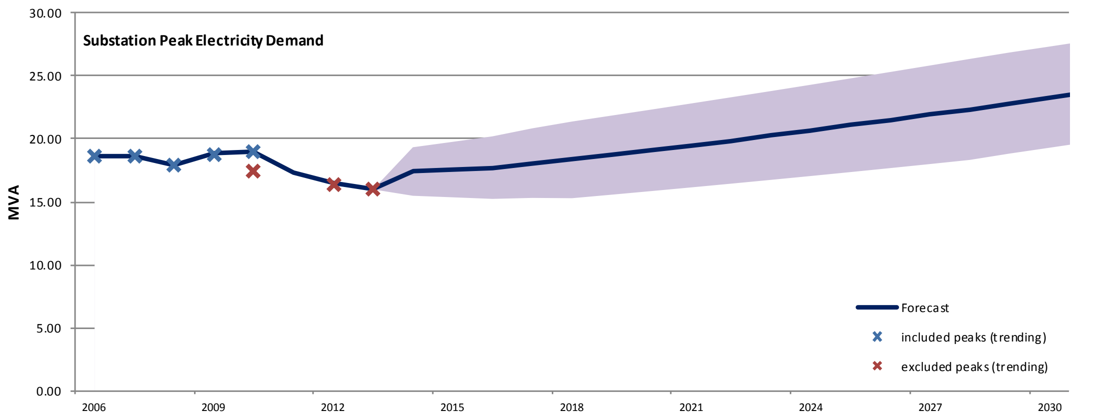
- Population age structure
- Life cycle effects on household and family formation, birth rates, rates of migration and labour force participation
- Industrial composition.

To translate the economic growth forecast for various sectors into the load mix for each substation, the Installation Control Point (IPC) registry data was mined to draw out the Australian New Zealand Standard Industrial Classifications (ANZSIC) data for each ICP connected to the substation. This gave a proportion customer distribution into four sectors, industrial, commercial, dairy and domestic. An average demand per ICP for each sector was then used to correctly allocate the load into each sector. Sector specific economic growth factors are applied to each sector to produce the forecast demand growth according to economic forecasts.

**Note – Average demand estimates could be augmented to reflect different seasonal customer patterns such as holiday homes in the Coromandel region.*

Results obtained

A summary of all data sources, growth factors and engineering control points is produced for each substation load forecast, providing a robust and transparent report for detailed review. Presented as a single page, the forecast outcome is narrated with the engineering decisions related to excluding and selecting datasets and in selecting the mix of historical trend, economic growth factors and customer load. Example substation load forecast reports are presented in Figures 6a and 6b.



Peak Demand - Confidence Forecast

	Tier 1			Tier 2			Tier 3		
	2014	**2016**	**2018**	**2019**	**2021**	**2023**	**2024**	**2026**	**2028**
Forecast	17.41	17.72	18.33	18.71	19.48	20.27	20.67	21.49	22.34
Lower Confidence	15.48	15.23	15.29	15.57	16.15	16.74	17.05	17.68	18.33
Upper Confidence	19.33	20.20	21.37	21.85	22.81	23.79	24.29	25.31	26.35
	Avg. Forecasted Growth		1.26%	Avg. Forecasted Growth		1.92%	Avg. Forecasted Growth		1.86%

Historical Load Analysis:

Year	Included	Reason
2006	Yes	
2007	Yes	
2008	Yes	
2009	Yes	
2010	Yes	
2011	No	Post load shift to Katere Rd.
2012	No	Post load shift to Katere Rd.
2013	No	Post load shift to Katere Rd.
Historical Trend	**0.57%**	**P.a. (calculated for year to 14-Aug-13)**

	Tier 1	Tier 2	Tier 3
Relative Weighting	**75%**	**25%**	**25%**

Econometric Indicators:

	Growth*	ICP Count**	MWh	Relative
Residential	0.39%	2,191	17,528	0.09%
Rural	2.60%	213	24,383	0.81%
Industrial	1.96%	154	17,629	0.44%
Commercial	2.42%	162	18,545	0.57%
			Weighted Growth	**1.92%**

	Tier 1	Tier 2	Tier 3
Relative Weighting	**25%**	**75%**	**75%**

*Source NZIER **Source ICP Registry - ANZSIC

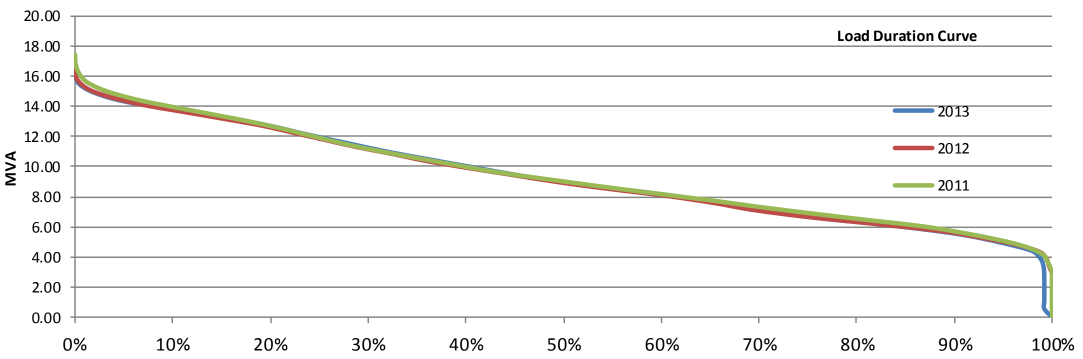
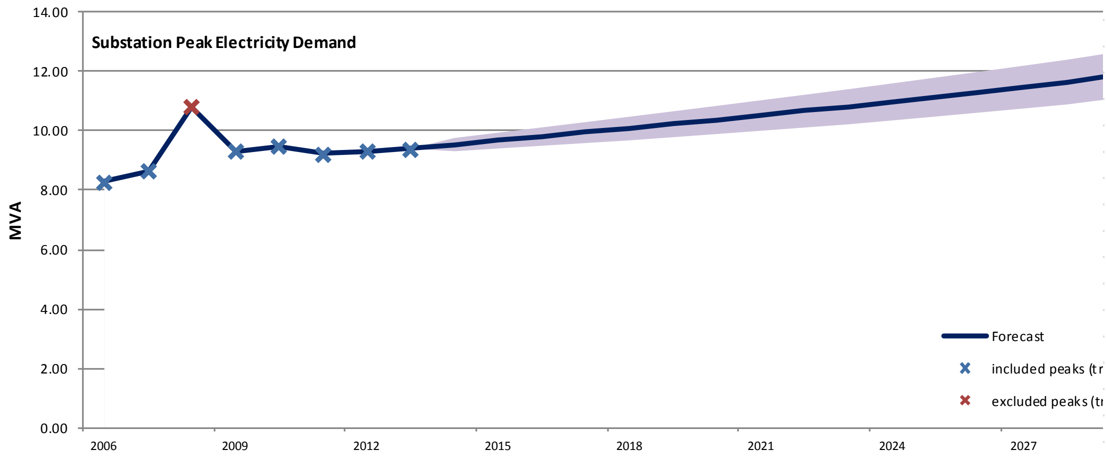


Figure 6a – Bell Block Substation Load Forecast Summary Report

Note: Bell Block Substation has had recent load transfers to the new Katere Substation, so the underlying historical trend growth from the years prior to transfer has been used, combined with econometric growth factors.



Peak Demand - Confidence Forecast

	Tier 1			Tier 2			Tier 3		
	2014	2016	2018	2019	2021	2023	2024	2026	202
Forecast	9.54	9.81	10.08	10.22	10.51	10.81	10.97	11.30	11.6
Lower Confidence	9.31	9.50	9.68	9.79	10.00	10.22	10.35	10.62	10.8
Upper Confidence	9.76	10.12	10.47	10.66	11.03	11.40	11.60	11.99	12.3
	Avg. Forecasted Growth		1.34%	Avg. Forecasted Growth		1.36%	Avg. Forecasted Growth		

Historical Load Analysis:

Year	Included	Reason
2006	Yes	
2007	Yes	
2008	No	High Peak, removed, suspect historical data.
2009	Yes	
2010	Yes	
2011	Yes	
2012	Yes	
2013	Yes	
Hitorical Trend	1.43%	P.a. (calculated for year to 04-Sep-13)

	Tier 1	Tier 2	Tier 3
Relative Weighting	100%	75%	50%

Econometric Indicators:

	Growth*	ICP Count**	MWh	Relat
Residential	0.97%	2,045	16,360	0.4
Rural	2.36%	335	11,468	0.7
Industrial	1.22%	39	1,335	0.0
Commercial	2.39%	229	7,839	0.5
			Weighted Growth	1.7

	Tier 1	Tier 2	Tie
Relative Weighting	0%	25%	50
	*Source NZIER		**Source ICP Re

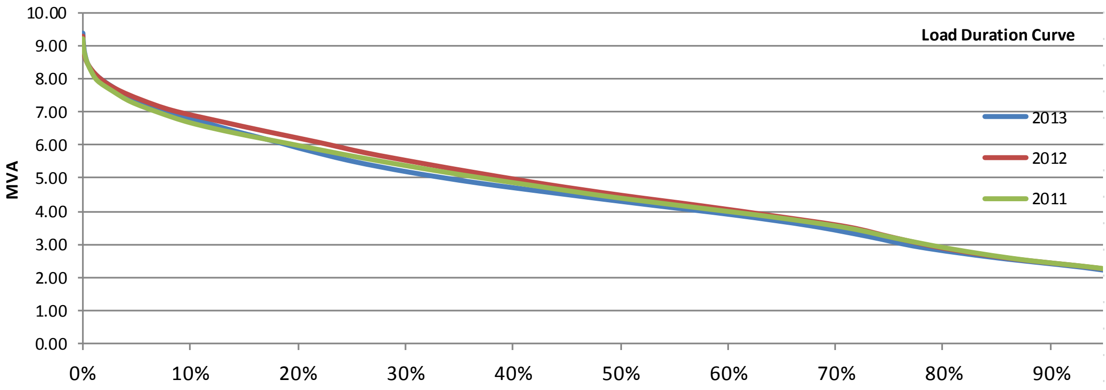


Figure 6b – Kerepehi Substation load forecast summary report

Note: A high peak has been excluded from the historical data in 2008, and greater weight is initially placed on the historical trend growth, transitioning to equal weighting with the econometric growth at the end of the period.

A comparison of the load forecast results for 67 Western Region substations showed that the average growth was 1.11%, a small decline of 0.12% across that sample. The scatter plot (Figure 7) shows the difference between the new 2014 calculated growth rate and the previous rounded 2013 growth rate, with most results being within one percent of the previous result. The largest outlier is a 2.5% growth rate associated with a known dairy processing load increase committed after the 2013 load forecast. In summary, the new load forecast methodology has produced results that are reasonably close to the previous forecast, meaning that growth investments planned on the basis of the forecasts can be expected to be stable. However, because of the increased rigour in the forecast methodology, Powerco can invest in network development with greater confidence.

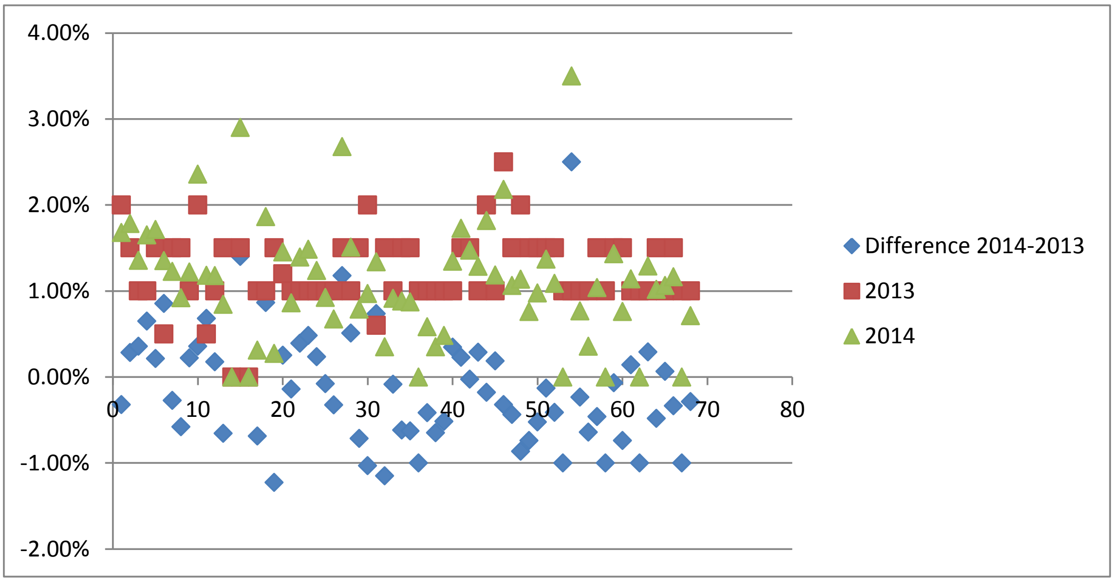


Figure 7 – Scatter plot of 2013 forecast versus 2014 (new) forecast and difference

Continuous improvement

There are a number of areas where we expect to continuously improve this new approach to load forecasting. The methodology will continue to evolve, informed by an analysis of the annual actual load results compared to the earlier forecast. Improved customer intelligence will provide further indications of customer load intentions and growth trends, or the penetration of PV distributed generation. We will incorporate feedback on our load forecast approach from external review.

The load forecast methodology will be further extended to distribution feeder level forecasting. This is challenging because of the number of load transfers and embedded generation that can affect the feeder load data, and the difficulty in screening this data to obtain real maximum demands and produce a historical trend. The development of Powerco's Outage Management System may provide greater traceability in load transfers to allow this factor to be more easily accounted for.

In producing a megawatt forecast and converting to an apparent power megavoltampere demand, a power factor for the load is required. Further improvements in gathering historical data for substation power factors is required, given somewhat patchy data available at present.

Conclusion

Powerco has designed a methodology that produces a consistent, defensible and repeatable load forecast, combined with a transparent documentation of the data sources, growth factors and engineering control points applied to the forecast that is sufficient to withstand robust review. The improvements in the load forecasting methodology have overcome a number of limitations of the legacy approach, providing greater confidence in the results. A consistent and repeatable load forecast is essential for determining the optimum network developments required to securely supply customer demand into the future, and to allow electricity distribution businesses to invest quite considerable sums in the expectation of future demand growth with confidence.

References:

[1] *Future Growth – Outlook for economic activity around Powerco's networks*, John Stephenson, NZIER report to Powerco, July 2013.