REF: S026

Tuesday 27 May 2008

TO: John Gleadow
Director Transmission
Electricity Commission
John.Gleadow@electricitycommission.govt.nz

FROM: Ranil de Silva
System Studies Group NZ Ltd
ranil.desilva@ssgnz.com

VAr Measurement at Unity Power Factor
Revision 0

1. Introduction

The Connection Code, which is an attachment to the Benchmark Agreement requires unity power factor from peak loads in the Upper North Island and Upper South Island as measured at the GXP during the 12 coincident regional peak demand periods.

There is a question of how the power factor should be measured at the GXP's and what practical issues could arise in complying with this obligation to maintain unity power factor at peak load. This technical note briefly discusses how compliance with unity power factor could be measured.

2. Power Factor

The power consumed by the demand is commonly expressed using the following components :

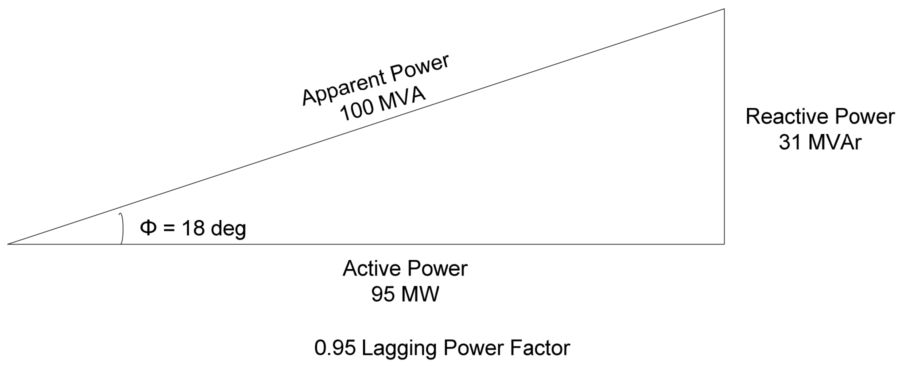
- Active power in MW
- Reactive power in MVAr
- Apparent power in MVA

The power factor of the demand is the ratio of the active power to the apparent power. Power factor is also known as Cos Φ because it is equal to the cosine of the angle subtended between the apparent power and active power (which equals the phase angle subtended between the voltage and current). A lagging power factor means that the demand is consuming reactive power whilst a leading power factor means that the demand is producing reactive power [1].

A demand at unity power factor requires no exchange of reactive power with the connected system.

Figure 1 shows the mathematical relationship between these components for a 100 MVA demand with a 0.95 lagging power factor. In this case the active power is 95 MW and the reactive power is 31 MVAr.

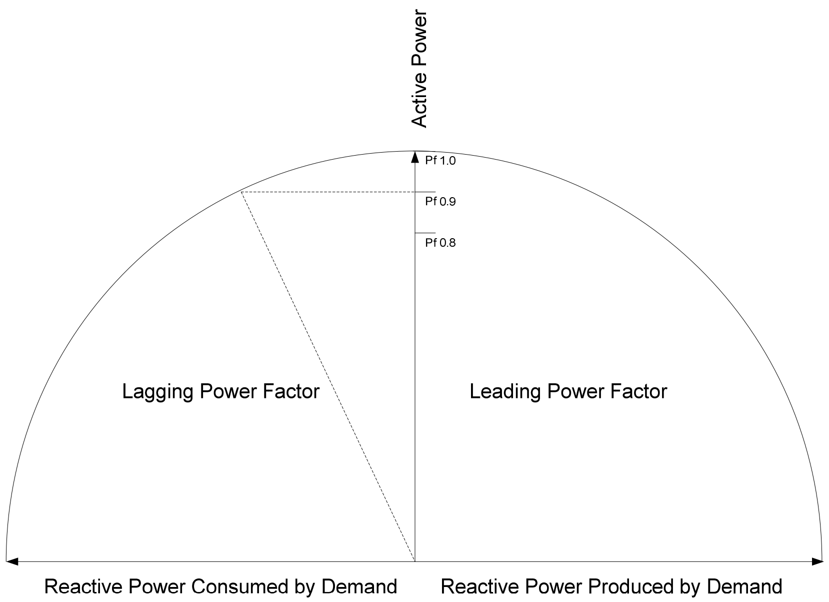
Figure 1. Relationship Between MVA, MW, MVAr, and Power Factor



[1] To simplify this analysis we only consider here the ‘displacement’ power factor for non-distorted sinusoidal voltages and currents. If there are high levels of distortion then the analysis would also have to consider the ‘distortion’ power factor.

Figure 2 how the demand can change from a leading power factor (consuming reactive power) to unity power factor (no exchange of reactive power) to a leading power factor (producing reactive power). A particular case is shown with 0.9 lagging power factor.

Figure 2. Demands with Lagging and Leading Power Factor



3. Metering Standards for VAr-Hour Meters

Grid exit points are required to have VAr-hour meters of accuracy Class 2 or Class 3. The Class 3 meters are the least accurate and are considered as the worst case in this analysis.

"Electricity Governance Rules 1 May 2008 – Part D Schedule D1 Code of Practice D3 Appendix 1 - Table 1 Standards for Electricity Meters" requires that Class 2 and Class 3 electronic var-hour meters meet IEC 61268 'Alternating Current Static VAr-Hour Meters for Reactive Energy (Classes 2 and 3)'.

IEC 61268 specifies the accuracy listed in Table 1 for Class 3 meters at high currents (which are assumed to occur at peak load in this analysis).

Table 1. Accuracy for Class 3 VAr-Hour Meters with Balanced Loads

Sin Φ	Cos Φ Power Factor	% Error Limit
1	0	± 3%
0.5	0.87	± 3%
0.25	0.97	± 10%

The % Error is defined as :

$$\% \text{ Error} = 100 \times \frac{(\text{Reactive Energy Registered by Meter} - \text{Reactive Energy})}{\text{Reactive Energy}}$$

It follows from this definition that when the power factor is close to unity and the reactive energy approaches zero, then the % error will become very large. This is why the % error limit increases from ± 3% to ± 10% as the power factor increases from 0 to 0.97 .

However, the large % error at unity power factor does not imply that the VAr-Hour meters cannot be used to check that the power factor is close to unity. What is required in practice is that the reactive energy is close to zero over the half hour measuring period.

Table 1 suggests that the absolute reactive energy error limit (as opposed to the % error limit) is about ± 0.03 of the apparent power measurement over the entire range from zero to unity power factor. (At 0 pf the absolute error limit in MVAr is ± 0.03 of the MVA and at 0.97 pf the absolute error limit is ± 0.024 of the MVA).

At close to unity power factor the active power is almost equal to the apparent power, therefore the error in absolute reactive energy can be expected to be about ± 0.03 of the active energy measurement

It should be emphasised that this analysis is based on an extrapolation of performance from IEC 61268. (This was discussed with Ron Beatty of the Electricity Commission who is in general agreement with the principles of this analysis.)

Also note that IEC 61268 has been superseded by IEC 62053-23 which requires smaller error limits of ± 4% for Class 3 meters and ± 2.5% for Class 2 meters at 0.97 power factor. It is expected that this would result in even smaller reactive energy errors at unity power factor than the present meters meeting IEC 61268.

4. Compliance Implications for VAr-Hour Measurement at Unity Power Factor

The preceding analysis suggests that a Class 3 VAr-Hour meter is likely to have a reactive energy error limit of about ± 0.03 of the active energy measurement when measuring the peak demand at close to unity power factor.

For example if a demand is drawing 100 MW at unity power factor for 1 hour, then the active energy meter can be expected to register about 100 MWh and a Class 3 VAr-Hour meter may register between - 3 MVAr-hours and +3 MVAr-hours.

This suggests that when considering compliance with the unity power factor requirement, an allowance should be made for a Class 3 VAr-Hour meter reactive energy error of about ± 0.03 of the active energy measurement. This would correspond to a power factor of 0.9996 leading or lagging.

Similarly a Class 2 VAr-Hour meter can be expected to have a reactive energy error of about ± 0.02 of the active energy measurement. This would correspond to a power factor of 0.9998 leading or lagging.

If new meters are installed in compliance with the new higher accuracy standard IEC 61268 then a higher level of accuracy could be expected.