Active versus Passive Power Factor Correction

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Background

Capacitor based Low Voltage (LV) Power Factor Correction systems have been the accepted technology for correcting power factor for at least the past 50 years. There have been many improvements in capacitor designs over the years and properly designed, these systems can be reliable and rugged. Having said that, there are many of these systems installed that struggle to cope with harmonics, leading power factor, system response time and temperature issues. Whilst most, if not all, of these challenges can be catered for with correct design, correct component selection and quality manufacture, there are alternate technologies available that should be considered. Over the last few years, Active Systems or Static VAr Generators (SVGs) have become available for LV applications and are challenging conventional power factor correction equipment. Resellers of these SVG systems are very quick to point out some of the shortcomings with conventional capacitor based power factor systems but not so quick to discuss limitations and disadvantages of the newer generation SVGs. This document attempts to discuss the pros and cons for both technologies and then describe the very latest developments in control of power factor, namely, the Hybrid System.

History of SVG Technology in New Zealand

Metalect Industries combined with the Engineering School at Canterbury University to fund and direct research into Active Systems for 3 phase applications in 1996-1998. This culminated in publication of a PhD thesis by Edward Arnold Memelink in 1999. From there, single phase prototypes were built and tested. Metalect Industries and a technical team from Canterbury then extended the design to 3 phase, obtained government research grants, and units were built and site tested, notably on the Queenstown Gondolas. Whilst successful in electrical terms, the systems could not be economically manufactured due to component limitations of the time and by 2006, the projects were abandoned. Several related products were spun off as ongoing products for Metalect Industries and several of the ZVX units (Zero Crossing By-Pass units) have been installed in many sites around New Zealand.

Conventional Capacitor Based Power Factor Systems

There is a very wide variety of Capacitor based systems available but the overall technology is not complicated. A controller measures parameters, calculates how many kVAr are required to correct a lagging power factor and switches the capacitors onto the bus accordingly. Conceptually, very simple. Depending on the particular site conditions, harmonic blocking reactors may be required to prevent harmonic currents causing overheating in the capacitors. Almost without fail, forced air cooling by way of fans is required and regular inspection and maintenance is highly recommended. This type of power factor correction equipment has been built for many years and many switchboard builders, panel manufacturers, electrical contracting companies, and individual sites have built systems with varying success dependant on their level of appreciation of the issues. Unfortunately, many systems fail early due to a variety of problems. Experienced designers and manufacturers can and do design systems that have working lives of >15 years, even in very arduous site conditions. The fact is that not all of these Capacitor Based Systems are created equal, and lower cost designs usually have severe limitations. The following table summarises the good and bad of these cap-based systems, the market dominant design, as used in Australasia.

Pros and Cons of Capacitor Based Systems			
Benefits		**Deficits**	
Proven technology when correctly designed	Larger switchboard builders and specialist companies know what they are doing	Cannot control leading power factor	There are very few sites where this is required, and even then, it is often better to find the cause and fix it directly
Utilises available switchgear	Contactors, MCB's, fuses	Can be slow to react (but not always)	Often not required. However, there are capacitor based systems that are specifically designed to act sub-second (ie: kVArCorrect's Rapid Tray)
Simple to maintain	Ensure air flow as designed, capacitor current within specifications, temperature within specification	Old capacitors may be prone to leaking	Modern capacitors are optionally fire retardant resin filled.
Simple to repair	Replace contactors, capacitors, MCB's, fuses, etc. All done by any Electrician without system shutdown (if designed correctly)	Generate significant heat	True, but active systems generate even more. If the available cooling cannot handle a capacitor system, it absolutely cannot cool an active system

Low cost test equipment	Current meter, temperature measurement. Capacitance meter not required (if the current is correct, so is the capacitance)	Can produce system resonance issues	This is so rare, we have never seen it in over 500 installations and counting…
Easily expanded	Add more capacitance in very small lumps as site grows	Considered to be Old Fashioned	A matter of image only
Reliable	Capacitor failure does not take whole system off line. Saves customer money in penalties by continuing to operate	Risk of fire in the event of capacitor failure	Modern capacitors, combined with correct design, completely mitigate this.

Active Power Factor Systems (SVGs)

Although SVGs have been available for several years from the traditional suppliers (Schneider, ABB, Siemens, Frako, etc) their pricing has often been prohibitive. In the last few years, Asian manufacturers have released products into the Australasian market. In reality, there are actually less than five Asian manufacturers with some of them allowing their product to be brand labelled something different, so it appears there is a greater variety of SVGs on the market than there actually is. This is the case in New Zealand where the same units are available from different sources with different names on them. Conceptually, SVGs are simple but require significant elegance in the electronic design due to the large number of components. Flexibility is excellent and there is no doubt that as electronics become simpler and more reliable, these systems will thrive. However, there are some facets of these systems that need to be considered carefully so as to achieve reliability, maintainability and expansion cost effectiveness. Similarly to the table above for capacitor based systems the following is a table of Pros and Cons for SVGs.

Pros and Cons of Static VAr Generator Systems			
Benefits		**Deficits**	
Fast and accurate correction of power factor (leading or lagging)	When working as designed, there is no doubt that the power factor correction delivered is excellent	Higher cost of installation than conventional capacitor based systems	Made up of unit purchase price plus 3 x CT's plus air conditioning. Even without air conditioning in the switchroom, the cost of SVGs is higher
Often physically smaller than capacitor systems	Wall mount options are lower cost than the racked large SVGs	Expensive to expand because the units come in big lumps. EG: if the system is 5kVAr short of achieving target, minimum step is 30kVAr at >$5-7k installed	Contrast a capacitor based system where an extra 5kVAr may be a few hundred dollars only

More reliable than poorly designed conventional systems	Certainly not true for properly designed capacitor based systems	All the eggs are in one basket, causing potential large penalty tariffs to the user	If the unit has a fault and goes 'off-line' all power factor correction is unavailable. If a capacitor fails in a conventional system then the rest can continue
		Generates almost twice the heat as a capacitor based system and is specified for lower ambient temperatures to start with. Air conditioning is required	Capacitor based systems have a higher ambient temperature specification. This is critical in non-airconditioned rooms over summer months
		Usually very high MTTR (mean time to repair) times – recommend 100% complete spare system backup to avoid 0% power factor control to the site (maximum exposure to penalties)	When the whole system is offline, the full penalty tariffs will be incurred by the end user. One way around this is to use multiple 30kVAr units rather than a single larger unit, although this is a huge cost and only minimizes the problem rather than solving it
		Units have more capacitance internally than conventional systems. Worse, these capacitors are electrolytic type with corrosive acids inside	True, and the lifetime of electrolytics is known to be significantly less than high quality MPP caps as used in capacitive type power factor systems. See kVArCorrect's papers on *Design Problems in Power Electronics*
		Higher risk of larger penalty tariffs with any failure due to combination of large single unit size combined with high MTTR figures	Modern capacitor based systems can totally fail too, but the MTTR is significantly lower and can be fixed by local electricians without 'return to base' or very specific skill sets

A Combination of the two Technologies – THE HYBRID SYSTEM

Potentially, a Hybrid system that combines the two technologies can mitigate the cons of both technologies whilst accentuating the pros. The scenario would be, for a 100kVAr requirement, to provide 70kVAr of capacitor based modules with a 30kVAr SVG. In every case where the author has investigated the case for control of leading power factor, it has been found that the amount of leading kVAr required is less than 30% of the total requirement. For example, in data centres in moderate temperatures a leading power factor of about 25kVAr is common, but when the temperatures are hot or cold requiring significant air conditioning units to operate, the power factor is typically 150-300kVAr lagging. In this general example, 275kVAr of capacitive and 30kVAr of SVG can cater for all situations. This Hybrid system is undoubtedly more cost effective than a full 300kVAr of SVG, in addition to not having all of the negative points shown in the tables above. The system will produce far less heat and will not be completely off-line due to an SVG electronic malfunction, as there would be significant capacity in the capacitor based section of the system to avoid the bulk of penalties. Further, if the hybrid system is modular such as kVArCorrect's systems, there would be an option of a redundancy module as a secondary back up, or a solution to the rare event of an SVG failure. What would happen is a capacitor based module of the same size as the SVG can be substituted while the SVG is away being repaired. In this way, the client will not have penalty tariffs imposed. The comparative pros and cons of the three technologies are summarised in the following table - the third column relates to kVArCorrect's Hybrid system, which was developed specifically to overcome the limitations of both capacitor-based systems and active systems. It uses a traditional capacitor-based approach for bulk power factor correction, with a smaller active system to handle high speed as well as leading power factor requirements. The Hybrid system is designed to have the best of both technologies whilst offering superior reliability.

	Capacitor system	Full active system	Hybrid Systems
Cost	Low	High	Medium
Can handle leading power factor	No	Yes	Yes
Can provide exact kvar requirements	No	Yes	Yes
Operates at near real time compensation	No	Yes	Yes
Type of capacitors used	Oil or dry type	Electrolytic	Electrolytic and dry
Capacitors switched at zero crossing point	No	n/a	Yes
Easily maintained	Yes	No	Yes
Heat generated	Moderate	Higher than capacitor systems	Moderate
Easily expanded	Easy	Difficult	Easy
Cost of expansion	Low	High	Low
If electronics fail, still deliver kvars	Yes	No	Yes
Can be maintained and repaired on site	Yes	No	Yes

To expand on this table: Fully active systems are only price competitive for smaller systems, as they come in fixed minimum sizes. When choosing an active system, it is important that the end user looks at the cost of expanding the system if required. For example, if you start with a 100kVAr active system, and would like to expand by 20kVAr, a complete 100kVAr module will need to be purchased, as opposed to increasing the size of the existing system or even purchasing a smaller module. In general, fully active systems are expensive to expand in this way, compared to capacitor-based and Hybrid systems.

Fully active systems are completely electronic and if the electronics fail in any way, the whole unit shuts down and most often will require repair and/or replacement at the supplier's factory. Whilst the system is off-site being repaired, the customer is exposed to full power factor penalty tariffs and peak demand charges from the electricity supplier. In comparison, capacitor-based and Hybrid systems can be repaired on-site by electricians using readily available components. More importantly, these units will still function as a capacitor-only system if the power electronics fail, meaning the customer is still protected against power factor penalty tariffs and peak demand charges from the electricity supplier.

Fully active system suppliers often criticise as well as exaggerate the heat load of capacitor-based systems, and the frequency of capacitors overheating. In reality, a fully active system will generate more heat per kVAr than a capacitor-based system, and effective cooling is even more critical – with many fully active systems requiring placement in an air-conditioned room. Further, active system vendors often criticise capacitor-based systems for having a large number of capacitors. While this does mean the traditional units take up more space, the power factor capacitors used are safer and more reliable. This is because in a fully active system, electrolytic capacitors are hidden from sight to smooth the DC bus within the unit. These capacitors are filled with very corrosive acids to increase the microfarads of capacitance (allowing them to be much smaller physically).

Overall, the kVArCorrect Hybrid system would be recommended over a fully active system for the following key reasons:

1) Lower installed cost than SVGs
2) Lower risk of penalty tariffs being imposed
3) Can be repaired locally by any electrician, no specialists are required
4) Can be simply and cost effectively expanded

Summary

While fully active systems can provide exact kVAr requirements for both leading and lagging power factor in near-to real time, they can be extremely expensive, and are totally return-to-base in the event of electronics failure (leaving the site completely unprotected against power factor penalties and peak demand charges). Clients are often shocked to discover the cost of expanding a fully active system is at least as high as the original installation. Capacitor-based systems are designed to be field-repairable by registered electricians, allowing for continuous power factor correction – as opposed to the fully active system being completely off-line and off-site for repairs.

Hybrid systems only rely on the active electronics for less than 25% of the overall available corrective kVAr's, meaning 75% or more of the power factor correction is still available on-line to mitigate the potential penalties, should the electronics require repair or servicing. Hybrid systems combine the speed and control benefits of a fully active system, with the maintainability and reliability of a capacitor-based system.

About the author

Allan Ramson is the owner of kVArCorrect Limited and has worked extensively in the Australasian Power Factor market for over ten years. Allan and other engineers at kVArCorrect are ex-employees of Ampcontrol and Metalect Industries in Rotorua, and have been involved with Active System technology in New Zealand for many years. Also having been closely associated with over 500 power factor correction systems installed, it is with significant experience in the market that this document has been written. kVArCorrect designs and manufactures capacitor based power factor systems, Hybrid Capacitor/SVG systems, a range of power quality controllers, and SVG add-ons. Additionally, kVArCorrect sells SVG systems in 30kVAr, 50kVAr, 100kVAr and above sizes.