Harmonics & Power Factor Systems

Author: Allan Ramson (NZCE, BEng, MBT) March 2019
General Manager kVArCorrect Ltd.

History

Back when the electrical world was simple, and electronic control of electrical loads had not yet been invented, industrial and commercial buildings only had direct on-line motors as the source of motive power. These motors consumed power, produced useful work and by and large, ran at power factors ranging from 0.6 to 0.9 lagging. This was the way it was from the very first electric motors in the early 20th century. However, very soon, industrialists wanted to adjust the speeds of motors and so the Ward Leonard Generator sets were developed. These used a direct on-line motor to drive a DC generator which then drove a DC motor. DC motors are easily speed controlled and there is no impact on power factor. This was the standard method of controlling motor speed until the 1950's when Thyratrons were used in place of the Ward Leonard system.

Thyratrons were developed in the 1920's from radio type valves – effectively, they had the characteristics of modern SCR's but used vacuum tube and mercury arc technology. Although they could be used to provide speed control of motors, they were not the dominant design until the demise of Ward Leonard Generators in the 1950's. Thyratrons were the first 'electronic' means of motor controls and they were the first real source of harmonic pollution. Similar to today's SCR's and IGBT's, these produced 5th, 7th, 11th and 13th harmonic distortion. Up until this point, power factor had been basic, being just a matter of providing sufficient capacitors (or synchronous condensers) to correct the lagging power generated by the motors. Easy, reliable, long lived and easily maintained.

To complicate things, electric utility companies started using ripple control to manage water heater loads in the early 1950's. Ripple control is the superimposing of an AC voltage at a frequency somewhat above the fundamental 50Hz supply frequency, onto the supply. Ripple signal receiving devices were installed at every household switchboard and when the ripple signal was injected, typically when the supply authority needed to reduce total load, the ripple signal receiving devices turned the water heating circuit off. When the total load was reduced to a manageable level, the supply authority would turn the ripple system on again and the receiving devices would restore power to the water heaters. Typically, water heaters were turned on and off twice per day, corresponding to heavy load situations such as meal times and also periods of cold when heating was required. These ripple signals are also harmonic pollution.

Overall, harmonics on the supply grew steadily from 1950 onwards and from about 1990 it is fair to say that the amount of harmonics present on the supply has positively exploded. This is mostly due to lower cost electronics, advances in motor control, the desirability of speed control, and the need to control overall energy use by only operating plant at the speed actually required, not full synchronous speed all the time. The lowering of cost of electronics from the 1970's onwards has prompted the growth of the computer industry and as this has developed, more and more harmonic pollution has been a side effect.

How does this affect Power Factor Correction Systems?

Specifically, how does this affect the capacitors used in most power factor systems? Although the size of power factor systems is measured in kVAr's, these systems are actually banks of capacitors that are designed and built to deliver a certain capacitance in microfarads (µF). Where the parameter kVAr will vary with applied voltage (the 'V' in kVAr), capacitance is the same at all applied voltages and frequencies. For example, a 100µF capacitor will be 100µF at 1V or 1000V. That same 100µF capacitor will be 100µF at 50Hz or 500Hz. This means that the capacitor will consume power at all frequencies. The formula for current in Amperes:

$$I = 2\pi fEC$$ where f is frequency in Hz, E is voltage in V, and C is capacitance in µF.

Before harmonics, capacitors were designed to handle only the current that existed at 50Hz. With harmonics, capacitors have to handle the currents at all frequencies that exist on its supply. Capacitors are quite good at handling current in itself, but all capacitors have losses, and these losses exhibit themselves as heat. The capacitor has to try and handle this additional heat produced by the harmonic currents, and it is the ability of the capacitor to handle (or not) this excess heat that is the issue.

Harmonic Blocking Reactors

Thus, harmonic blocking reactors (chokes) were developed. As the name suggests, these reactors are designed in such a way as to form a 'tuned' circuit with the capacitors, where frequencies above the tuned point are attenuated to a safe level for the capacitors to handle. There have been, and still are, a number of 'tuning points' that are selected for various reasons, and reactors manufactured accordingly. Because the 'nasty' harmonics that are by far the most prevalent are the 5^{th} (250Hz), 7^{th} (350Hz), 11^{th} (550Hz) and the 13^{th} (650Hz), the tuned frequency for the reactors has to be somewhat below these frequencies. By far the most common tuned frequency is 189Hz, and so the vast majority of power factor systems contain 189Hz harmonic blocking reactors. These do not actually block the frequencies above 189Hz, they merely attenuate them (formula for attenuation available from the author upon request). Hence, the capacitors are protected from excess currents causing overheating and the power factor is still corrected.

Electronic Options

With the rise of harmonics on the supply, Electronic Power Factor Correction Systems such as Static VAr Generators (SVGs) are being offered into the market. SVGs are not susceptible to harmonic overload, and often a sister product called Active Power Filter (APF) are suggested to counteract the harmonics in the system. Unfortunately, these two pieces of electronics often introduce unreliability because they consume significant power themselves and produce almost twice the heat load of conventional capacitor based power factor systems. The effects of harmonics are very often exaggerated to extol the virtues of these new electronic devices.

Summary

kVArCorrect can offer all types of power factor and harmonic mitigation systems and we are available throughout New Zealand and Australia for an unbiased assessment of what may be best for any site.

About the Author

The opinions expressed here are the researched views of Allan Ramson, General Manager, kVArCorrect Ltd. All claims have been substantiated by testing and observations from the Australasian market between 2007 and 2018. Having been associated with the design, manufacture and supply of many thousands of power factor capacitors and over 500 power factor systems, kVArCorrect are confident that they can assist with any power quality enquiry.

For Enquiries, please contact your local
Account Manager Claire-Elizabeth Ramson:

ClaireRamson@kVArCorrect.com Phone: 0435 798 323