Utilization of Canceling Reactive Currents to Improve Power Factor

by Robert T. Emmet, PhD

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In Industrial Circuits, the heavy use of induction motors, with their associated magnetizing currents, increases the amperage demanded from the Utility. These circuits are inductive with a Power Factor (PF) less than unity. It is customary to balance the inductive reactance of these circuits and to restore the PF toward unity by adding capacitors (CAPS) in parallel with the inductive loads or in parallel with the main plant feeds at the service entrance. When the inductive and capacitive reactances are matched, then the circuit is in parallel resonance and the amperage demanded is minimized. ypically 3000 to 4000 micro farads are added per phase to match the inductive reactance of a 100 HP inductive 480 volt motor. To maintain the balanced reactance, the capacitors must be switched on/off with the motors. If the CAPS are on while the motors are off, the plant goes capacitive**,** which increases the amperage demand. This complex switching task is often simplified by installing a variable capacitor bank at the service entrance with a feed-back control maximizing the Plant Power Factor. Such variable capacitor banks raise the plant PF, eliminating the PF Penalty from the bill, but they do not correct the PF within the plant nor do they reduce the I squared R power loss within the plant.

In AC circuits, as frequency increases, capacitive reactance decreases and inductive reactance increases. RCL (Resistance/Capacitive/Inductive) Resonance occurs at the frequency where the Inductive Reactance of the circuit equals the Capacitive Reactance of the PF CAP Bank. In modern circuits there are substantial harmonics caused by VFD (variable frequency driven) Motors and other solid state loads. If any existing harmonic frequency coincides with this resonant frequency, the magnitude of that harmonic increases significantly. If that harmonic is of a low order, 3^{rd}, 5^{th}, 7^{th} , or $<^{th}$, then the effect of that harmonic can distort the system voltage or current wave form**.** This distortion causes problems such as motor overheating, breaker tripping, transformer overheating or damage to capacitors and motors. Also, in the ac circuit, a serious voltage condition occurs as a result of this Harmonic RCL Resonance**.** The circuit total impedance (including the CAP) is very high at the resonant frequency. If the VFDs generate harmonic current at the resonant frequency, large harmonic voltages will be developed at the CAP and at the transformer bus. These harmonic resonances are very / ynamic conditions which create voltage transients that travel throughout the plant often burning out motor field coils and overheating transformers.

PF Cap banks are particularly vulnerable to the detrimental effects of power system harmonics. Most CAPS are designed to operate up to 110% of the rated voltage and 135% of the rated kVAR. Large magnitudes of current and voltage harmonics can exceed these limits and cause serious CAP bank damage. Since Capacitive Reactance is inversely proportional to the frequency, CAP banks act a sinks for the current harmonics in the system. This often causes CAP fuses to blow or CAP damage when fuses are not present. Incidentally, because of this damaging RCL Resonance effect set off by harmonics, CAPS or CAP Banks are not used for PF Correction in Navy Ships.

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Energy Savings Integrators

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2. Other USES References in earlier posted papers by Emmet and Ray.