Alarm on the set of a Major Motion Picture

By Guy Holt | Mar. 2021

A recent incident on the second unit set of a major motion picture clearly demonstrates how current and voltage harmonics can cause erroneous meter readings. Two 50kW SoftSun fixtures were rigged to a Lull and punched through diffusion to light special effects wire work done against a green screen wall on an outdoor set (pictured left.) In the course of production the set flipped to the other side of the makeshift stage, which necessitated that the Lull with the two 50kW SoftSuns move to the opposite side which was powered by a separate generator that was also powering the video village. As soon as the SoftSuns were switched-on alarm broke out in the video village because the line frequency jumped drastically.

The generator operator ran back to the plant to find the digital frequency meter on the generator fluctuating wildly but the engine rpm was stable, which was a clear counter-indicator of trouble since frequency is a function of engine speed. When he read the frequency of the power with his digital multimeter, the generator operator found that it was a stable 60Hz. What was the cause of the erroneous frequency readings on the generator digital meter and the meters on the DIT cart? To answer that question we must first understand how SoftSuns work.

Figure 1: Two 50kW SoftSuns rigged to a Lull

To be flicker free at high camera speeds, SoftSun Plasma lamps operate on DC, which means that their power supply (ballast) must convert the AC provided by the generator to DC. It does this in a very similar fashion to the Diode/Capacitor front end of HMI ballasts (described in the previous session) but without switching the DC back to an alternating waveform. In other words, one difference between an electronic HMI ballast and SoftSun ballast is that the HMI ballast goes one step further and generates an alternating current out of the DC generated by the diode/capacitors where the SoftSun ballast does not.

HMI ballasts and SoftSun ballasts differ in several other respects as well. Since SoftSun ballasts operate three phase, their rectified AC voltage consists of six pulses per cycle (as illustrated below in Figure 2), rather than the two created by the diode bridge of a phase to neutral HMI ballast.

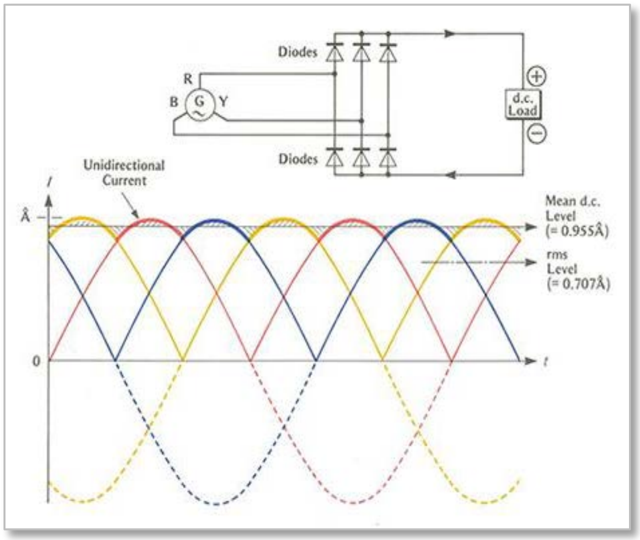

Figure 2: Operating 3-phase the rectified AC voltage of SoftSuns consists of six pulses per cycle.

And, given their intended use for high-speed cinematography, the SoftSun ballasts use much larger smoothing capacitors (100,000 uP in total) across the three-phase rectifier to remove the DC ripple of the six pulse rectified AC. As such, SoftSun ballasts also draw current in short bursts of a high magnitude because of the short interval in which its' smoothing capacitors must charge. But, unlike an HMI ballast, a SoftSun ballast draws two pulses of current for each half cycle of the AC supply voltage (as illustrated below in Figure 3), rather than the one drawn on each phase by an HMI ballast.

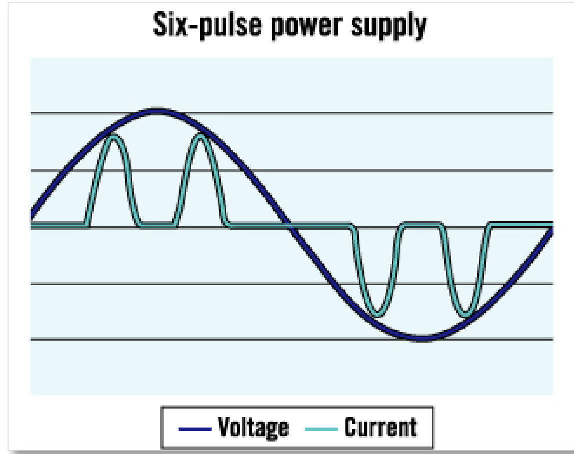

Figure 3: a SoftSun ballast draws two pulses of current for each half cycle of the AC supply voltage

The final difference between a SoftSun ballast and an HMI ballast is that, without a Switch Mode Converter final stage, the DC value of the rectified AC is a function of the AC supply voltage (0.955 times the AC amplitude, or 1.35 times the rms value.) Which means that the DC voltage to the lamp will vary depending on whether the AC supplied by the generator is 208v or 240V. So that the SoftSun's Plasma lamp receives its 'prescribed DC value, a SoftSun ballast substitutes three SCRs (thyristors) for three of the diodes on the bridge. A SCR is a solid-state device like a diode but with a third electrode, which prevents the device passing current forward until the third electrode is "triggered."

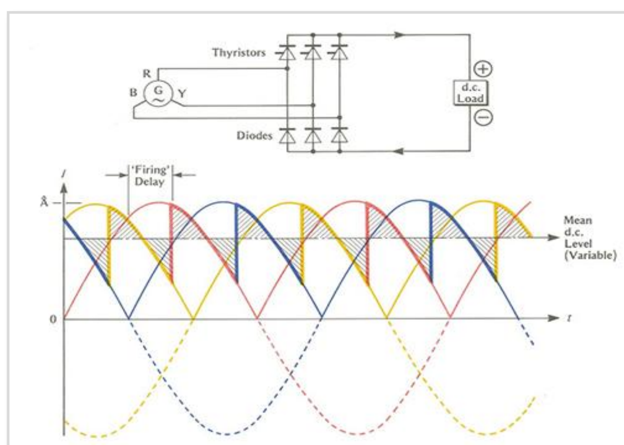

Figure 4: Thyristors on the rectifier bridge of SoftSun ballasts regulate the DC voltage to their lamp

Since the SCR will not conduct until signaled to do so on the third electrode, the “firing” can be delayed in order to reduce the value of the DC output. An electronic circuit provides a firing pulse with a variable delay, so that the rectified AC waveform appears as illustrated above in Figure 4. The mean DC level – that is, the line where areas above and below it are equal – will be different with differing delay times. Thus the bridge can be used to give different DC output levels simply by controlling the electronic delay circuit. The ballast’s 100,000 uP capacitor bank then removes the remaining voltage ripple in the DC output. As such, a SoftSun ballast, like an HMI ballast, draws considerably more power than would a comparable kW of incandescent lamps. The power factor of a SoftSun ballast is .55, which means that a 50’000W lamp will draw an apparent power of 90’720VA (Note: Luminys Corporation, the manufacturer of SoftSuns, will be introducing pfc power supplies that will draw 40% less power in the near future.)

As can be seen in Figure 3 above, the current drawn by the SoftSun’s bank of smoothing capacitors is quite distorted. With two spikes in each half cycle, it does not resemble the sinusoidal current drawn by an incandescent light at all. A Fast Fourier Transformation of this distorted current reveals it consists of a number of harmonic currents in addition to the 60hz fundamental.

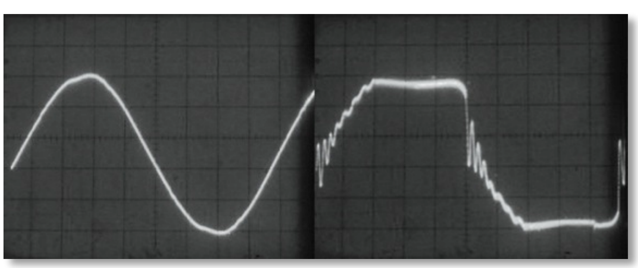

Figure 5: Right: the voltage waveform of the soft power of a generator distorted by the harmonic currents drawn by a non-linear load like a SoftSun. Left: the same load on the hard power provided by the grid.

On the soft power of a generator, the numerous harmonic currents drawn by SoftSuns, interact, according to Ohm’s Law, with the impedance of the generator to create voltage drop. And, since the smoothing capacitors consume power only at the peak of the voltage waveform, the voltage drop caused by the harmonic currents occurs only at the peak of the voltage waveform. The result is a “Flat Topped” voltage waveform with multiple zero cross-overs, or “Ringing”, as the line voltage switches from positive to negative.

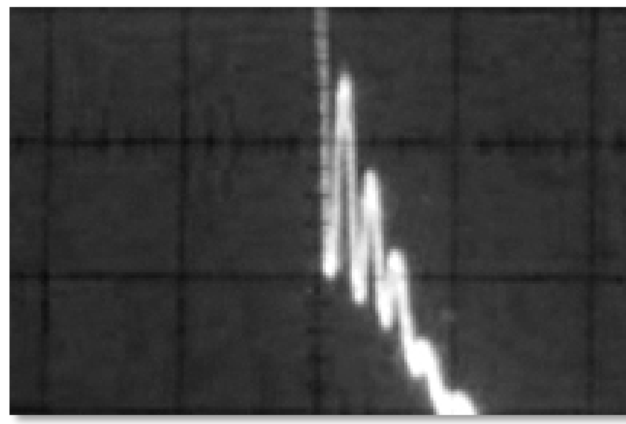

Figure 6: multiple zero cross-overs, or “Ringing”, in AC voltage caused when the harmonics drawn by a non-linear load like a SoftSun encounters the high impedance of a generator.

Since many digital frequency meters (like those on the generator and the DIT cart) measure frequency by counting the number of zero cross-overs per second, they are easily mislead by the ringing voltage waveform and will read each spurious zero cross-over as a complete half cycle resulting in a frequency reading much higher than the actual line frequency. If the voltage waveform distortion is really severe, it can also cause voltage regulator sensing problems in the generator.