A Case Study in Energy Savings

The Application of Harmonics Limited Technology in AT&T Call Centers

Beginning in the latter part of 2013 and continuing into 2014, Harmonics Limited (by Jefferson Electric) installed forty-three SysteMax units in six AT&T Call Center facilities throughout the states of Arizona, Arkansas, Colorado, Iowa, Missouri, and Oklahoma. This project was a key element of AT&T's corporate wide Energy Savings Program; the investment in which was justified by the energy savings accomplished within a three year timeframe. The following narrative and report describes the third harmonic problems experienced in the AT&T Call Centers; and how HL's Harmonic Suppression technology eliminated the harmful current, improved electrical system power quality, and generated significant energy savings in the process.

The report prepared by JD King, Engineering Physicist, BOC/CEM describes the facility design, discusses harmonic current and its effect on the system, explains the implementation of technology to eliminate the problem and the benefits derived.

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The AT&T Call Center is typically designed with a 75kva to 112.5 kVA transformer providing power line isolation for a large number of Single Phase Computer Loads throughout the Facility.

Referring to ***figure 1,*** we see an example of the typical computer power supply frontend. The input power to the power supply is from the secondary side of the 75kva isolation transformer and is 120 vac rms phase to neutral. The input voltage waveform is the standard U.S. Power Line frequency of 60 Hertz which is 8.33 ms for ½ cycle and 16.67ms for one full cycle of the voltage sine wave. ***However***, the rectifier recharges the DC capacitor only on the peaks of the Sine wave of voltage, so the total ½ cycle current impulse conducted through the rectifier is 2.78 ms and the complete current cycle is only 5.56ms. Therefore, even though the voltage supplied is 1/16.67ms or 60 Hertz or the fundamental frequency, the current is being sourced into the Rectifier at 1/5.56ms or 180 Hz or the 3rd harmonic of the fundamental frequency.

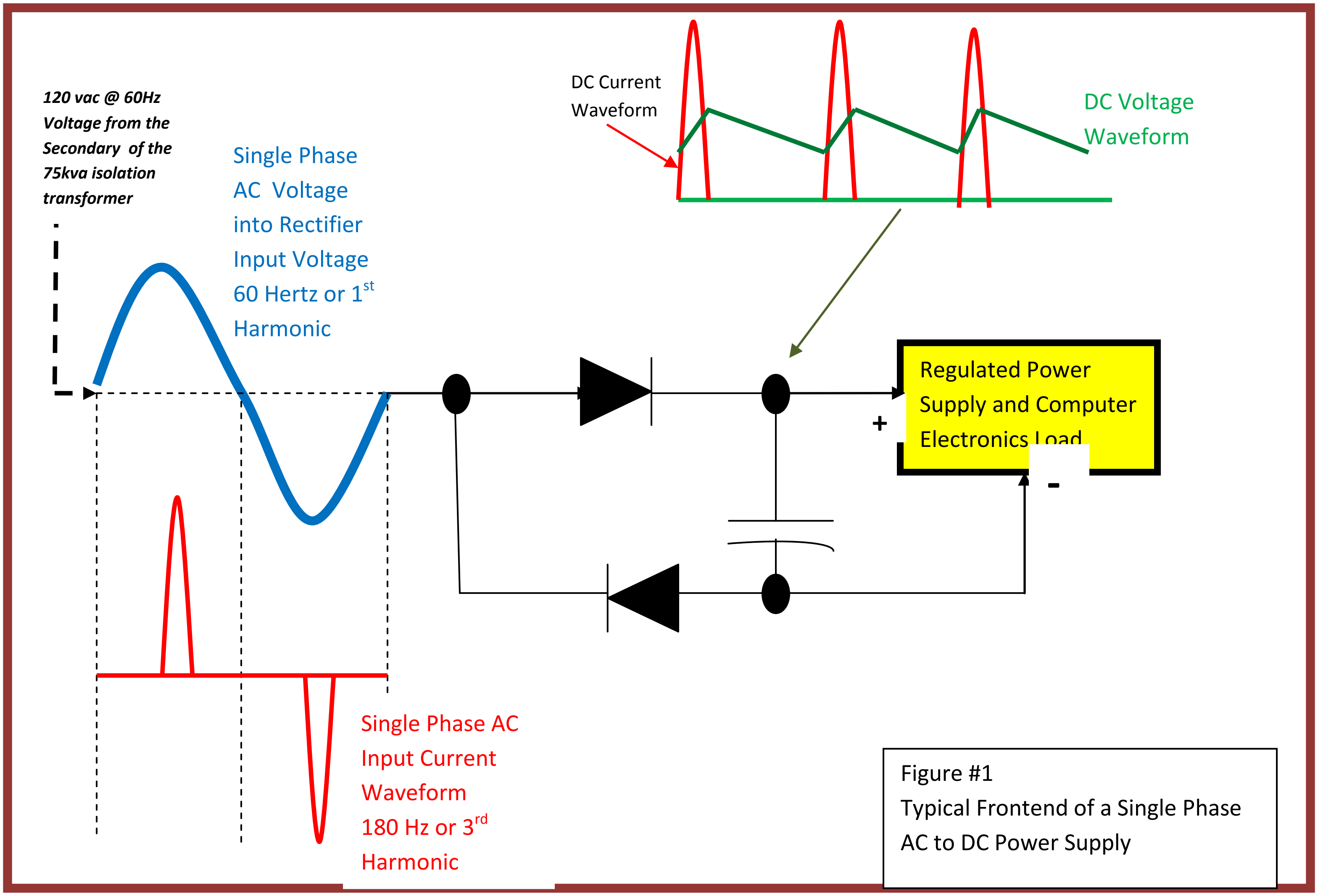


Figure #1
Typical Frontend of a Single Phase AC to DC Power Supply

AC power is delivered throughout the distribution system at a fundamental frequency of 60 Hz.

Harmonics are defined as, "integral multiples of the fundamental frequency**."** For instance, the 3rd harmonic frequency is 180 Hz, the 5th is 300 Hz, etc. In the US, the standard distribution system in commercial facilities is 208/120 wye. There are three phase wires and a neutral wire. The voltage between any two phase wires is 208, and the voltage between any single phase wire and the neutral wire is 120. All 120 volt loads are connected between a phase and neutral. When the loads are linear and are balanced on all three phases (the same fundamental current is flowing in each phase) the fundamental currents in the neutral cancel and the neutral wire carries no current.

When computer loads(Non-Linear Loads) and other loads using switched mode power supplies are connected, however, the situation changes.

Switch mode power supplies draw current in spikes or pulses, which requires the AC supply to provide harmonic currents. The largest harmonic current generated by the Single Phase Switched Mode Power Supply is the 3rd Harmonic. The magnitude of this harmonic current can be as large as or larger than the fundamental current. Also generated, in smaller amounts, are the 5th, 7th, and all other odd harmonic currents.

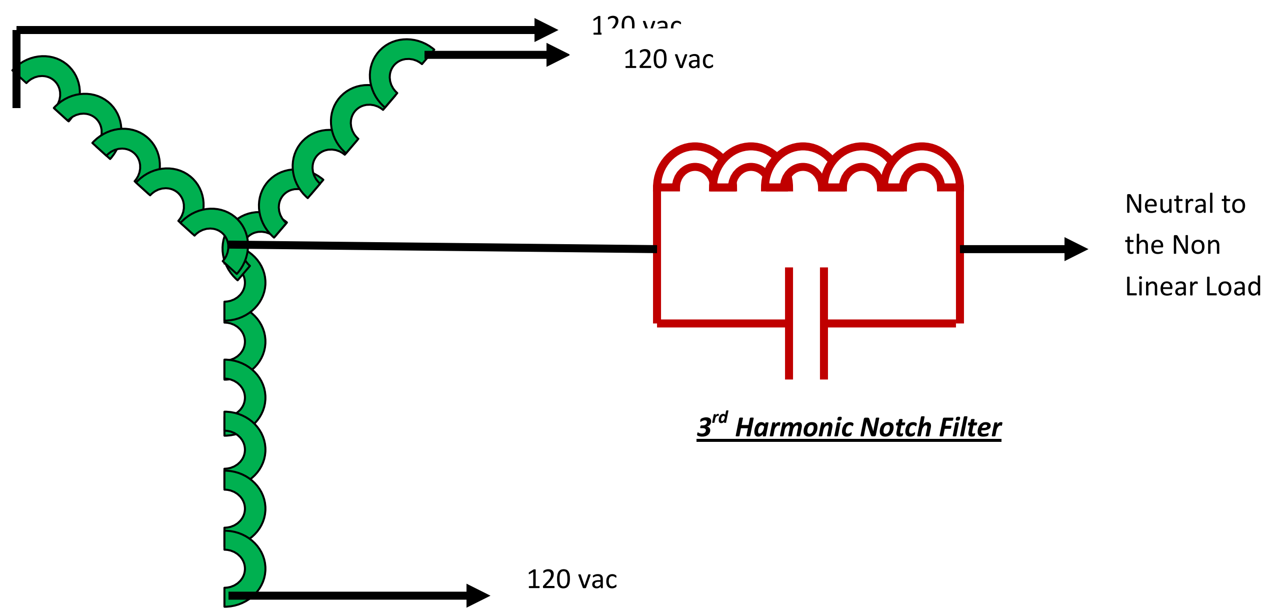
Like the fundamental current, most harmonic currents cancel out on the neutral wire. **However, the 3rd harmonic current, instead of canceling, is additive in the neutral.** Thus if each phase wire were carrying, in addition to fundamental current, 100 amps of 3rd harmonic current, the neutral wire could be carrying 300 amps of 3rd harmonic current. In many cases, neutral-wire current can exceed phase wire currents. **This extra current provides no useful power to the loads.** It simply reduces the capacity of the system to power more loads, and ***produces waste heat*** in the transformer, wiring and in the switchgear. When the 3rd harmonic current returns to the transformer it is reflected into the transformer primary where it circulates in the delta winding until it is dissipated as heat. The result is overheated neutral wires, switchgear, and transformers. This can lead to failure of some parts of the distribution system and, in the worst case, fires. In addition, waste heat in all parts of the system increases energy losses resulting in higher electrical bills. 3rd harmonic currents can increase electrical costs by as much as 10%.

Several methods have been employed to try to accommodate the higher currents caused by 3rd harmonics in the phase and neutral wires. The system can be over-sized. If a 115 kVA load is expected, a 150 kVA transformer can be specified, along with larger switchgear, and larger wires. The neutral wire can be doubled to enable it to carry the extra harmonic current. K-rated transformers, special transformers with more steel, heaver wires, and double neutral connections, designed to withstand the extra heat produced by harmonic currents, are available. Harmonic canceling transformers, often called "zig-zag" transformers, are designed to cancel the 3rd harmonic currents in the secondary winding, thus keeping them out of the primary winding. **Unfortunately, none of these methods actually keep the 3rd harmonic**

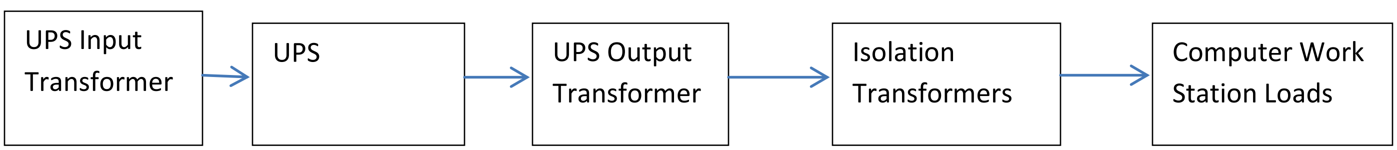
currents from flowing throughout the distribution system and none of them reduce waste heat and energy loss.

Rather than accommodating 3rd harmonic current, the Harmonic Suppression System keeps this current from ever being generated by the SMPS loads. The HSS consists of a parallel resonance LCR tank circuit tuned to the 3rd harmonic frequency. A property of this circuit is that it has a near infinite impedance at the tuning frequency and a very low impedance at all other frequencies. When connected at the transformer in series with the neutral wire, the HSS prevents the flow of 3rd harmonic current into the transformer. Since no 3rd harmonic current can flow into the transformer, none can flow out on the phase wires, and the SMPSs cannot generate any. (Basic laws of physics forbid the flow of current into a wire if it has no way of flowing out.) 3rd harmonic currents are eliminated in the distribution system from the transformer out to the furthest outlet. Engineers often ask, "Where does the 3rd harmonic current go?" The answer is, it doesn't go anywhere…it never exists in the distribution system – it is not allowed to be generated by the High Impedance filter.

The advantages of the HSS over "accommodation" technology are clear. Gone is the need to oversize a system to allow for extra capacity that cannot be used to support useful loads. Instead, the system can be "right sized," with installed capacity equal to what is really needed. Double neutral wires are eliminated. There is no need for k-rated or zig-zag transformers to handle the extra harmonic currents since these currents do not exist in the system. Waste heat caused by 3rd harmonic currents is no longer generated and system reliability is increased. Electrical power costs can be reduced as much as 10%. Depending on the operating hours of a facility and the cost of power, energy savings can pay back any extra cost of the HSS over accommodation technology in one to three years. Other techniques have very little energy payback.



AT&T call center computer loads are powered by UPS sources with a high output impedance when compared to the Utility Power Source. As a matter of fact – several more transformer stages are cascaded and must carry the triplen 3rd harmonic and all are adversely affected by the 3rd harmonic currents flowing in the transformers. Since transformer impedance is stated for 60 cycle currents and not for higher frequencies, the losses at higher frequencies are greater than they are at 60 hertz. 3rd harmonic currents are triplen harmonics and all return current from all 3 phases passes through the neutral and transformer heating and power distribution heating with a UPS is increased by 8 to 10% of the existing load on the system when the current load profile is made up of primarily of 3rd harmonic currents which is the predominant frequency necessary to power single phase loads.



Removing the triplen 3rd harmonic component means less heat wasted in kWh in the transformer and the power distribution system as well as in the UPS filters, inverter and rectifier.

<u>Your Energy Savings Calculations are as follows:</u>

(Transformer KVA Rating x 0.95)kw x (decimal % of load on the transformer) x 8760 hrs/yr = Annual Energy Consumption; Multiply this by 0.1 and you will get the approximate Energy Savings for Energy Wasted in the transformers and power distribution and the energy required to remove the excess heat from the building.