White Paper

Based on Power Use Reduction Transformer

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Abstract

The Tune® filter reduces home or business electric power consumption by introducing a passive, inductive transformer into the neutral of the load center or panelboard. The Tune® filter is applicable in single and multi-phase electric power systems in buildings that do not employ their dedicated sub-station and where there is measurable current on the neutral main conductor.

This report has been prepared on behalf of Tune, LLC. Tune provided Sagacis with full access to all materials for legal, patents, manufacturing, and engineering data. The engineering information came from the product design and development and third-party, post-installation engineering reports by NOESIS and CHI Energy Services.

This report is prepared by:

Andrew Naples

SAGACIS

4800 Taylors Court

Marietta, Georgia 30068

anaples@sagacis.net

Andrew Naples, SAGACIS Owner, and Chief Technical Officer, is a manufacturing consulting engineer with almost 50 years of experience in the electrical equipment marketplace. As defined by Underwriter's Laboratory standards' UL 891, UL 1558, UL 1149, UL 231, UL 1283, and UL 67. Mr. Naples received a BSEE from The Georgia Institute of Technology and a Finance degree from Georgia State University. Andrew has UL engineering experience working with the large electrical equipment manufacturers GE, Schneider Electric, Square D, and Eaton. His preeminent design work included the adaptation of the existing UL Standards to 100% rated electrical loads that demanded the highest reliability, such as in data facilities and internet farms.

Tune® can be found at energybytune.com and homebytune.com.

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Introduction

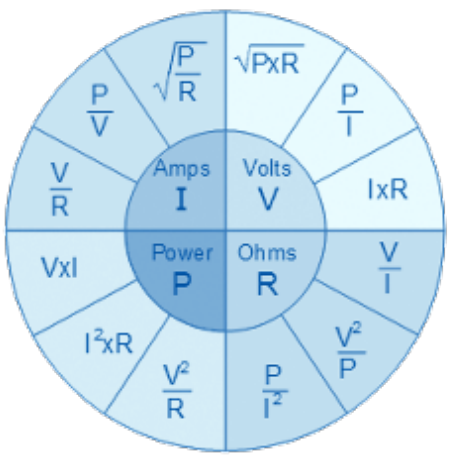
The Tune® facility filter has been designed and manufactured using the U.L.-approved packaging prevalent within the UL 1449 5th Edition SPD industry. It is listed by Underwriters Laboratories (UL) under the filter standard, known as U.L.1283, for safety purposes. The U.L. file number is E464646.

The Tune® filter is designed to be installed in parallel with the panelboard's neutral assembly. Because of the varied types of wiring of the branch circuit neutral conductors on the neutral bar, it is often required to have those "neutrals" reconnected to other terminal holes to reduce the overall resistance of those connections on the neutral bar and to provide two terminal locations for the installation of the Tune® parallel assembly. This rearrangement of the neutral conductors reduces the resistance value of those connection points. It reduces the "R" value in the power calculation by electronic KWH utility meters in the formula of $P= I^2R$. This lower resistance value on the neutral bar allows current flow through the lower resistive value Tune® assembly. This current flow is due to leading power factor loads that exhibit a capacitive current profile.

Under the U.L. 67 Standard, the neutral conductor is designed to secure a neutral termination under mechanical forces associated with a short circuit. Although it safely ensures the conductor, this mechanical design standard adds resistance to the circuit, which is used in calculating watts by the utility's KWH power meter.

The neutral conductors and the ground conductors are still bonded together at the service entrance, within the facility, and at the panelboard location on the secondary side of a step-down transformer, as required by the National Electrical Code.

The Tune® filter basis of design combines air core inductors with variable inductance values but a fixed resistive value approaching the Nano ohm range. The inductance of the device improves the power factor of capacitive profiled currents, which are referred to and measured as multiples of the 60-hertz fundamental frequency. These multiples are measured as odd and even harmonics beyond the 60^{th} harmonic. The filter has been found to reduce the overall harmonic distortion of the panelboard once installed. This paper will discuss the components and installation of the Tune® filter in further detail. Ohm's law is at work here.

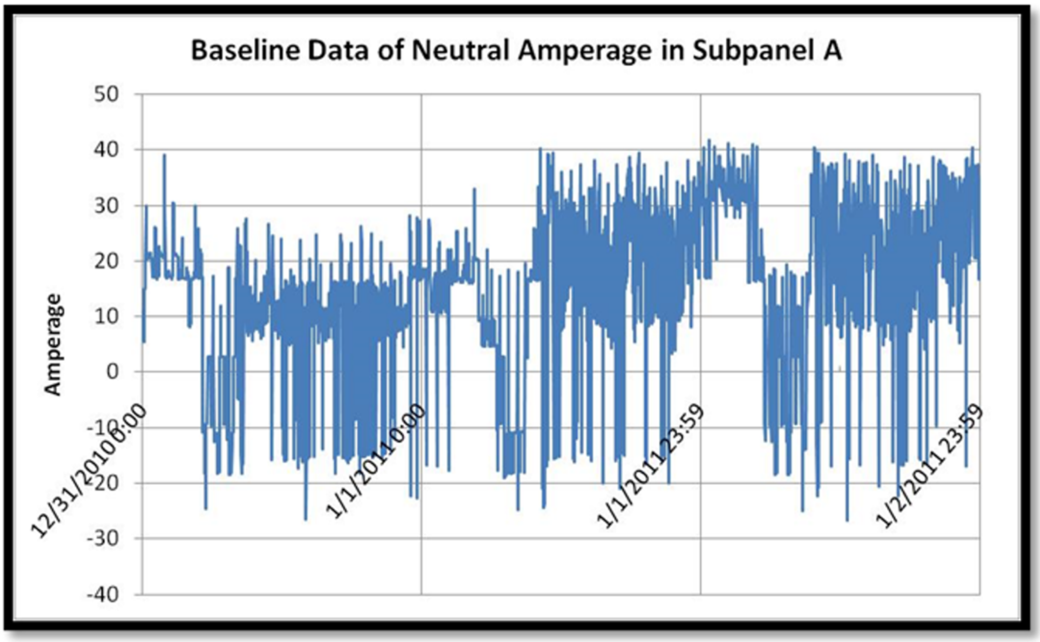


Tune® Impact

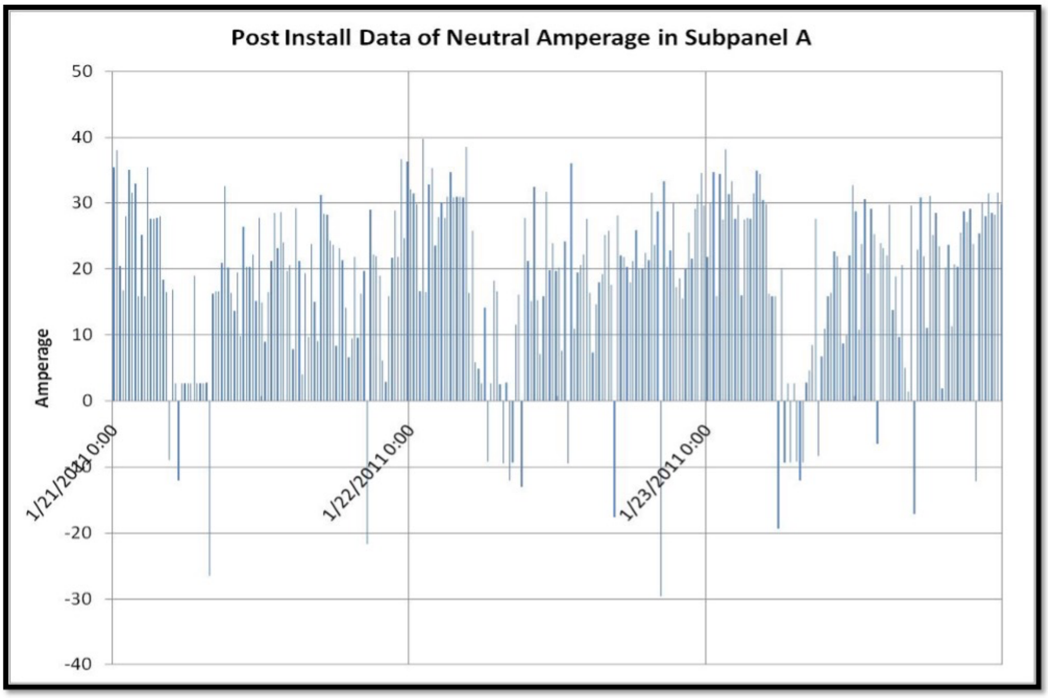
The images below reflect readings before and after installing Tune®. Additional background information follows.

- Early in our proto-typing and experimentation, a sizeable fast-food franchise group commissioned a study on the impact of the Facility Filter.
- The study was done on one location in Louisville, KY, in 2011 by a 3rd party (EE and Energy Management Company) who installed meters that tracked every amp consumed in each circuit in a panel along with the harmonic noise from both leading and lagging power factor equipment.
- The data was collected on a weekend with similar customer traffic (sales volume) and weather conditions (to meet IPMVP standards)
- The 72 hours of data collection were then compressed into a simple graphical presentation that follows.
- The net impact was a 10 percent KWH reduction on the location when the Facility Filter was installed.
- No comparison was made to the building's electric power company meter.
- Graphs reflect time compression images with/without below.

Before Tune® installation



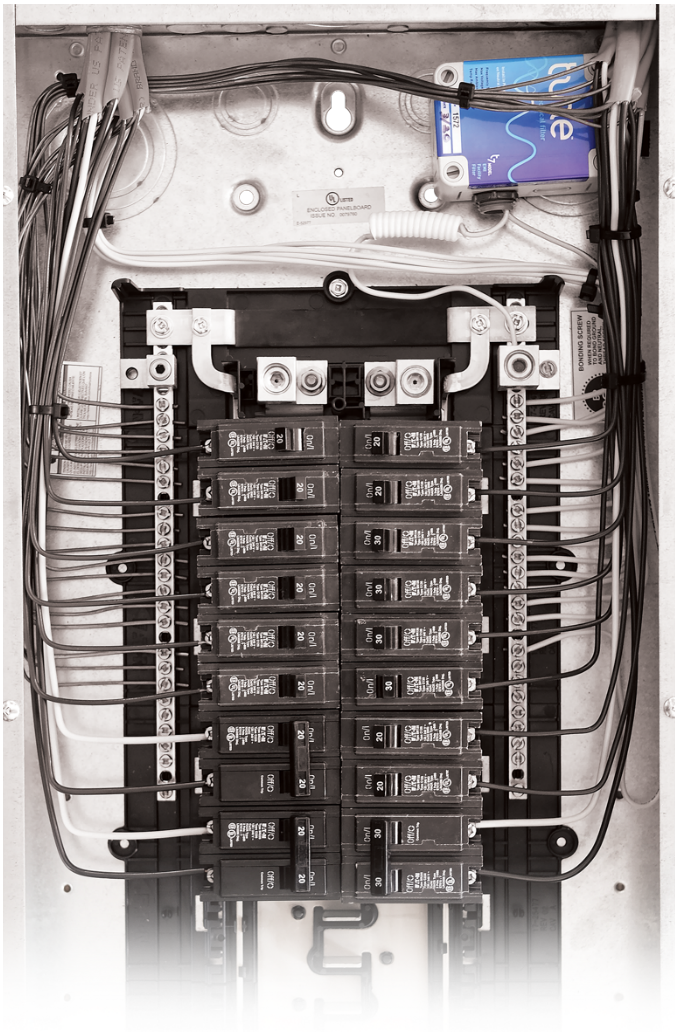
After Tune® installation



Effects of Tune® on load (breaker) panels

Tune® products have been certified by Underwriters Laboratories (UL) under the filter standard known as U.L.1283 for safety purposes. Tune® carries the UL seal under UL file E464646.

Tune® products are designed to be installed in parallel with the neutral assembly within U.L. 67 panelboards. The parallel installation ensures electrical safety from either an open or a short circuit within the Tune® assembly.



Tune® products, being inductive-transforming filters, are designed to not only improve the power factor of leading power supply loads but also to reduce the harmonic content of the current for those single-phase and three-phase circuits that exhibit harmonic characteristics (above 5% THD) beyond the fundamental alternating current (AC) 60 Hz frequency that is delivered to a building by local power companies. The current outside the fundamental frequency is typically created by leading power factor loads that convert alternating current (AC) power to direct current (DC) power to be used by electronic circuits that are in computer power supplies, appliances, TVs, audio equipment, variable speed motors and pumps, electronic controllers, drivers for LED lights and similar devices.

Effects on Local and Neighborhood Distribution Systems

Extensive testing has been done to determine if Tune negatively impacts the local power distribution system within a structure or the more comprehensive distribution network serving neighboring buildings. Tune® has no negative impact on the local power distribution system.

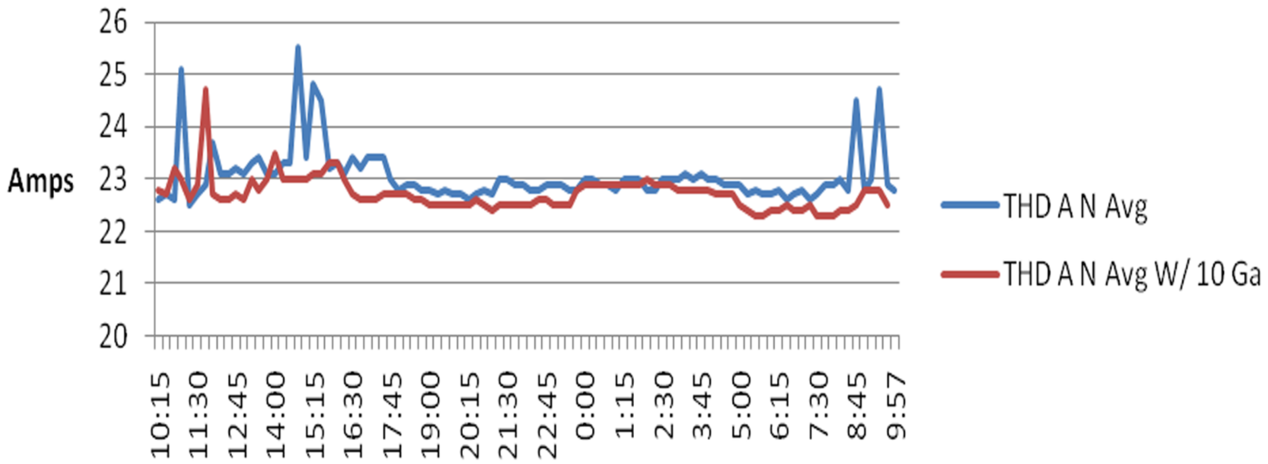
Impact on Total Harmonic Distortion

Tune products have been tested in single-phase and three-phase applications to determine if the total harmonic distortion is affected. Testing using Extech 382905, capable of measuring to the 99th harmonic frequency, has shown that the total harmonic distortion does not INCREASE with applying the Tune products but instead shows a measurable DECREASE in THD. This was true for both systems with high levels of total harmonic distortion due to many non-linear loads and systems that employed more resistive loads and, therefore, had lower total harmonic distortion. Using a Fluke 1735 and a Fluke 434, there were measurable reductions in the THD when the consuming loads were switching power supplies with a capacitive load profile, including T8 lighting fixtures and LED replacement fixtures for metal halide 70,125-, 250-, and 400-watt ballasts.

PS500 Meter Results

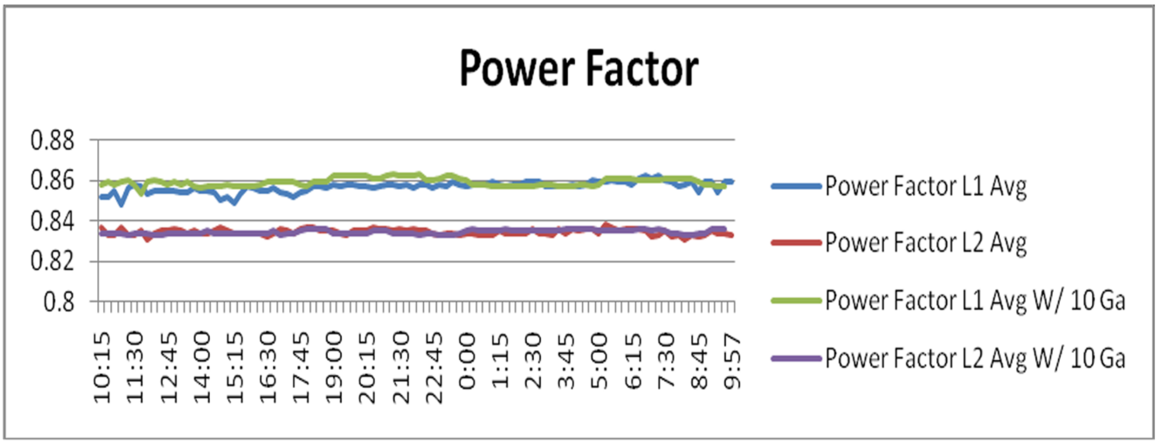
PS5000 Meter Measured	No Filter	With Filter	Units	Change	%Change
Voltage, Phase 1, Avg:	117.5	119.9	volts	2.42	2.06%
Voltage, Phase 2, Avg:	120.9	122.6	volts	1.70	1.41%
Current, Phase 1, Avg:	17.5	17.9	amps	0.36	2.06%
Current, Phase 2, Avg:	2.2	2.2	amps	0.01	0.66%
Current, Neutral, Avg:	16.0	16.4	amps	0.44	2.78%
Current, Neutral, Max:	20.8	22.1	amps	1.35	6.51%
Current, Neutral, Min:	14.3	14.9	amps	0.59	4.13%
Power Factor, Phase 1, Avg:	0.97	0.98		0.01	1.03%
Power Factor, Phase 2, Avg:	0.74	0.72		-0.02	-2.44%
True Power, Phase 1, Avg:	2.009K	2.105K	Watts	96.64	4.81%
True Power, Phase 2, Avg:	194.1	193.3	Watts	-0.76	-0.39%
VA Power, Phase 1, Avg:	2.061K	2.147K	VA	85.60	4.15%
VA Power, Phase 2, Avg:	262.6	268.0	VA	5.44	2.07%
VAR Power, Phase 1, Avg:	462.2	417.2	VAR	-45.00	-9.74%
VAR Power, Phase 2, Avg:	176.8	185.6	VAR	8.78	4.97%
Frequency, Avg:	60.0	60.0	Hz	-0.01	-0.02%
THD Current, Phase 1, Avg:	14.6	9.4	%	-5.20	-35.62%
THD Current, Phase 2, Avg:	79.8	49.8	%	-30.00	-37.59%
THD Current, Neutral, Avg:	14.6	9.0	%	-5.60	-38.36%

THD on Neutral Current Measurements, Fluke 1535



Impact on Power Factor

Power factor testing was performed using the Extech 382905 on 480Y/277 VAC, 208Y/120 VAC, three-phase, and 120/240 VAC single-phase systems with loads that required a neutral. While no measurable impact was observed using the Extech monitor, a change was recorded in the power factor when the Tune product was added to the circuit, when measured by a Fluke 1735, particularly with loads that included variable speed single phase drives, switching power supply-based lighting ballasts, and drivers for LED lighting.



Tune Impact on KWH

A recent load panel 30-minute comparative test without and then with Tune installed. The measurements were taken using the Summit Technologies Power Sight 5000 meter with flexible CTs. The PS5000 Report Writer software produced the output tables illustrated below. Every category of power usage was reduced with the Tune product installed.

MEASUREMENT	BEFORE	AFTER	UNITS	CHANGE	% CHANGE
Voltage, V2n, Avg	122.3	122.5	Volts	0.2	0.14%
Current, Phase 1, Avg	23.3	22.5	Amps	-0.8	-5.24%
Current, Phase 1, Max	26.5	25.9	Amps	-0.6	-2.23%
Current, Phase 1, Min	21.0	20.1	Amps	-0.9	-4.42%
Current, Phase 2, Avg	45.4	40.6	Amps	-4.7	-10.47%
Current, Phase 2, Max	67.5	67.3	Amps	-0.2	-0.28%
Current, Phase 2, Min	35.2	33.6	Amps	-1.6	-4.65%
Current, Neutral, Avg	9.7	8.3	Amps	-1.3	-18.85%
True Power, Phase 1, Avg	2810.8	2718.9	Watts	91.9	-3.27%
True Power, Phase 2, Avg	5468.6	4887.7	Watts	-580.9	-10.62%
True Power, Total, Avg	8278.2	7604.8	Watts	-673.4	-8.13%
VA Power, Phase 1, Avg	2848.4	2757.4	VA	-91.0	-5.19%
VA Power, Phase 2, Avg	5548.0	4976.7	VA	-571.3	-10.30%
VA Power, Total, Avg	8395.1	7731.7	VA	-663.4	-7.90%
VAR Power, Phase 1, Avg	-458.8	-458.3	VAR	0.5	-0.10%
VAR Power, Phase 2, Avg	-917.8	-927.8	VAR	-10.0	1.09%
VAR Power, Total, Avg	-1377.1	-1386.7	VAR	-9.5	0.69%
Total Power Factor, Phase 1, Avg	0.99	0.99		0.0	0.00%
Total Power Factor, Phase 2, Avg	0.98	0.98		-0.0	-0.19%
Total Power Factor, Total, Avg	0.98	0.98		-0.0	-0.59%
Energy, Phase 1, Elapsed:	0.7	0.5	kWh	-0.2	-23.55%
Energy, Phase 2, Elapsed:	1.3	0.9	kWh	-0.4	-33.35%
Energy, Total, Elapsed:	1.9	1.4	kWh	-0.6	-30.05%
VAH, Phase 1, Elapsed:	0.7	0.5	kVAh	-0.2	-23.52%
VAH, Phase 2, Elapsed:	1.3	0.9	kVAh	-0.4	-33.00%
VAH, Total, Elapsed:	2.0	1.4	kVAh	-0.6	-29.82%
VARH, Phase 1, Elapsed:	0.1	0.1	kVARh	-0.0	-22.13%
VARH, Phase 2, Elapsed:	0.2	0.2	kVARh	-0.0	-20.75%
VARH, Total, Elapsed:	0.3	0.3	kVARh	-0.1	-21.67%
Energy Estimated per Month	6043.1	5551.5	kWh	-491.6	-8.13%

Independent Lab Correlation

CHI Energy Services
PO BOX 7042
Rainbow City, AL 35906
256.490.0835
256.312.9185

May 2023

To Whom It May Concern:

By way of introduction, CHI Energy Services is a certified ESCO (Energy Services Company) partner. CHI's Mr. Hardin is a board-certified Association of Energy Engineers member. As of 2015, CHI Energy Services was the only state of Alabama Approved Vendor in Good Standing with the State of Alabama authorized to certify an energy project or product to US Dept of Energy Standards and apply the DOE Seal to that project or product. CHI Energy Services adheres to the International Performance Measurement and Verification Protocol (IPMVP) Volume 1 EVO 10000-1:2012 guidelines and ASHRAE Guideline 14 to form our analyses and use our proprietary software to build the linear regression energy models. Multiple countries developed these standards to ensure consistency in energy analytics and for energy professionals to use these standards globally as uniform guidelines and practices to assess energy savings projects (and products). CHI Energy Services' primary customer base is health care, hospitals, related medical facilities, and Professional Office buildings.

Before agreeing to accept the Tune inventors as clients, CHI Energy Services required a series of tests to prove the product's efficacy. Over months, those pilot tests were completed to our satisfaction.

CHI Energy Services has performed four studies on the Tune EMI Facility Filter in different commercial settings. Each project has been carefully reviewed and analyzed according to the IPMVP and ASHRAE standards. Each project has successfully reported savings of 10 percent or higher reduction of KWH usage. These projects included condominium common areas (18.7% savings), fast food restaurants (10.8% savings), auto dealerships (11.4% savings), and workout facilities (13.02% savings). With the analyses of these different projects, where the only change to the facility was installing the Tune products, CHI Energy Services can put the DOE Certification of Savings on these projects and the Tune products as products that reduce KWH consumption.

If you have any questions, please get in touch with me.

Respectfully,

Mr. S. Todd Hardin
President & CEO
CHI Energy Services, Inc.

Residential Field Data

Field testing has demonstrated the effectiveness of the TUNE PRODUCTS™ at saving electrical power in residential, 120/240-volt, single-phase applications. The data below represents a sample of the average monthly KWH electric savings in percentage consumed for residential customers who have installed the TUNE PRODUCTS™ EMI Facility Filter within a residence that exhibited a high use of drivers for LED fixtures, LED lamps, and switching power supplies for consumer electronic components.

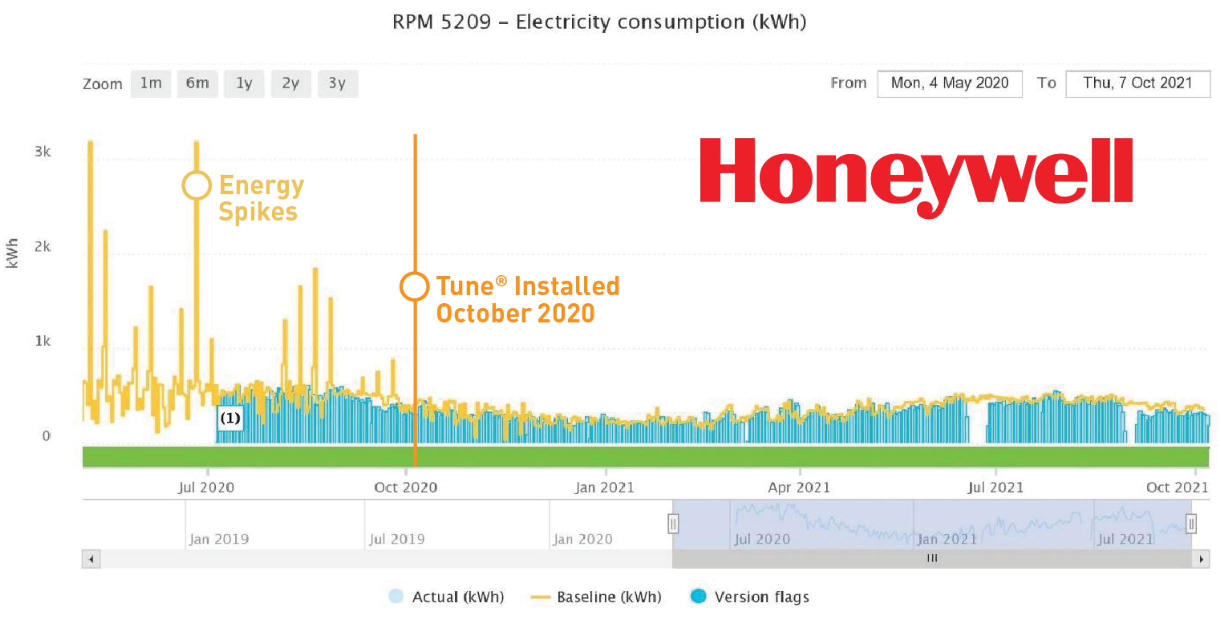
NAME	STATE	LOCAL POWER COMPANY	KWH SAVINGS
Donald Williams	VA	Dominion Power	20+%
Jeff Hammer	VA	Dominion Power	10+%
Craig Schwartz	VA	Dominion Power	15%
Dean Francis	VA	Dominion Power	10+%
Tom Freeman	VA	Dominion Power	8%
Barry Wisner	VA	Dominion Power	15%
Phillip Jones	VA	Dominion Power	10%
Morris Thompson	VA	Dominion Power	10%
Matt & Abi Tuiasosopo	GA	Sawnee EMC	14%
Ken & Alice McAvoy	GA	Sawnee EMC	15%
Jim Harrison	GA	Georgia Power	9%
Candy & Brett Parrish	GA	Thomasville Utilities	10%
Mike Rodrigues	AZ	AZ Public Service Co	14%
Judy Annibal	AZ	AZ Public Service Co	9%
Don Laney	AL	Sand Mountain EMC	20%
Mayor Geraldine	AL	Sand Mountain EMC	10+%
Rodney Clarke	AL	Alabama Power	9%
Shawn Ferrell	MI	Consumers Energy	10%
Art Depue	TX	PECOS EMC	10%
Merrin Mueller	MS	MS Power	10+%
Alan Lovelace	MS	MS Power	10%
Glen Mueller	MS	MS Power	12%

Commercial Field Data

The results of testing in commercial and light industrial applications are depicted below. The effectiveness of the Tune products in 480Y/277 VAC, three-phase, 4-wire applications show results ranging from 5 to over 20 percent. When the panelboard loads belonged to office LED and high output fluorescent T5 lighting loads (capacitive in nature with leading power factor), the measurable impact consistently exceeded a 10% reduction in KWH. When the same lighting loads were on the secondary side of a 480::208Y/120 VAC dry-type isolation transformer, the Tune products demonstrated limited impact because the 4.5% impedance (or higher) of the dry-type transformer exceeded the impedance of the Tune products.

For a table of examples of savings that third-party engineering companies confirm, please see Appendix A.

Honeywell Enacto Customer Report – 6 months before and 12 months after installing Tune – no more Peak Demand Charges after installing Tune.



Optimal Installation

Single-Phase Applications

Tune has repeatedly observed that the effectiveness of the products is highly dependent on the optimal installation of the device. Optimal installation ensures the proper amount of neutral current flows through the Tune device.

The Tune products and the nominal resistance of the neutral bus bar form a current divider. The current flowing in the incoming neutrals from the loads is divided between the neutral bus bar and the Tune. Only currents above the 60Hz fundamental frequency flow into the Tune's inductive transformer assembly. Thus, the installer must apply some level of analysis to ensure adequate current flows through the Tune products, as described in the introduction to this section.

It should be noted and assumed that the earth ground (green wire) is only bonded to the neutral at the service entrance of the 480Y/277 VAC, 208Y/120 VAC, or 120/240 VAC voltage systems. This entails that the building is already in compliance with NEC Section 250.4(a), 250.52 (A)(1), 250.53(D)(1), and 250.68(B). This same bonding occurs on the secondary of a 480:208Y/120 VAC dry-type isolation transformer. Since the ground within a panelboard is a non-current carrying conductor, unlike a neutral, no current should be on the ground before the Tune Products™ is installed. The measurement of a ground current within the panelboard before the Tune Products™ is installed should be reported to the building owner, as there might be a wiring error or equipment malfunction.

Optimal Installation

Three-Phase Applications

Like the single-phase application, Tune Products and the neutral bus bar form a current divider in three-phase applications. Although the goal remains to obtain an optimal current level in the Tune Products™, getting the same magnitudes in residential applications is sometimes tricky. This is primarily because most industrial three-phase power systems are expressly designed with balanced loads and neutral current minimization as a critical parameter. Optimal installation results are observed when careful adherence to installation guidelines is achieved by grouping neutrals closely on a straight, insulated standoff, neutral bus bar and surrounding the neutral wires with the leads of the Tune Products™ while ensuring the Tune Products™ leads are cut short as possible and do not cross any hot wires (inducing current into the Tune Products™).

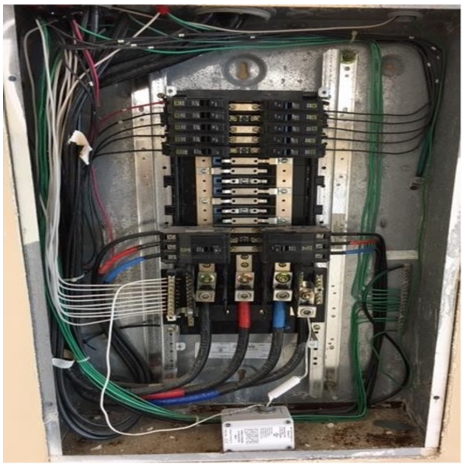


Figure 1: Typical Installation where code allows installing the Tune Products inside the panel.

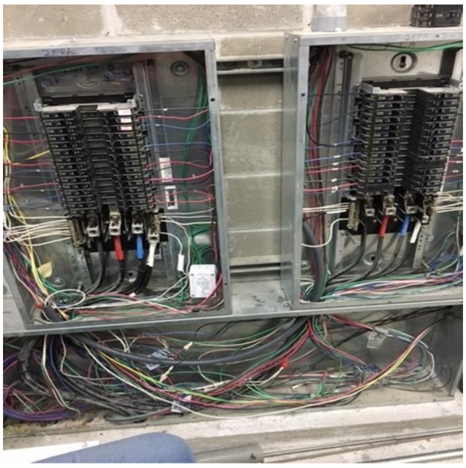


Figure 2: Subpanel served by the main panel- Used 1 Tune Filter to serve both panels.

UL Approved Installation Instructions

- A licensed Electrician should always install this unit.
- Be sure to follow Local electric codes and Safety procedures.
- An installation of the Tune Products™ should allow the device to form a parallel current divider on the neutral bus assembly located in an electrical box/load panel. The objective is to install the TUNE PRODUCTS™ in such a way as to expose the non-linear noise present on the neutral side of the circuit to the filter/transformer located in the Tune Products™. The Tune Products™ 's design does not cause the fundamental frequency to flow through it when installed in a parallel circuit. The TUNE PRODUCTS™ should never be installed in series!
- Generally, if the following condition is satisfied: (I > IN x .005), the Tune Products™ installation will be successful. Suppose there is insufficient current on the neutral circuit when attempting an installation. In that case, it may be necessary to “turn on” or add loads to the circuit to determine if the device acts as a current divider after installation. Typically, loads IN is < 4 Amps; the installer may need to increase the neutral current. It is best, however, if these measurements are taken during the normal operating conditions of the panel, as this is the environment in which the Tune Products™ will usually operate.
- Mounting the TUNE PRODUCTS™: The device is mounted outside the load panel. (Ensure all power to the electrical box/load panel has been turned off before installation.)
- Remove or open the electrical box/load panel door.
- Remove the panel cover from the electrical box/load panel.
- Identify where a “punch out” may be placed to allow the Tune Products™ to be positioned on the outside of the panel so that the leads will be as short as possible when connected to the panel.

- Ensure the “punch out” diameter will allow the nipple on the Tune Products™ case to pass through the electrical box/load panel wall so the two wire leads, and the nipple can be inserted into the electrical box/load panel.
- Attach the Tune Products™ to the outside of the electrical box/load panel using the nipple. Feed the two Tune Products™ leads and the nipple through the “punch out.”
- Using the Locknut provided, attach the Tune Products™ to the panel by sliding the Locknut over the two wire leads that are now protruding through the “punch out.” Secure the Tune Products™ to the electrical box/load panel by tightening the Locknut onto the nipple against the inside wall of the electrical box/load panel.
- The unit has two white leads. One lead is straight, and the other lead is coiled.
- Install the end of the coiled lead into the neutral main lug by loosening the screw of the neutral main lug, inserting the stripped end into the neutral main lug, and properly re-tightening the neutral main lug screw. Ensure proper contact. (If unable to use the neutral main lug, use a wire position on the neutral bus bar next to the neutral main lug.)
- Install the straight lead into the neutral bus bar by loosening a lug screw in an open position on the neutral bus bar, inserting the stripped end of the straight lead into the open position on the neutral bus bar, and appropriately tightening the screw. Ensure proper contact.
- Minimizing the device's resistance is essential as it acts as a current divider.
- Please trim the leads as short as possible.
- PLEASE NOTE: for better performance, have the electrician move the neutral wires as closely together as possible on the neutral bus bar(s) and surround them with the Tune Products™ leads. Use a measuring device to read AMPS on the neutral main going to the panel from the street. Take a reading of the AMPS flowing through the Tune Products™. If an increase in the current reading is needed, additional loads can be turned on to increase the readings. The objective is to see at least 4.0 milliamps of current flowing through the Tune Products™ per amp of current flowing through the neutral main. (for example, if the meter being used measures out to 2 decimal points, a reading of 10 amps on the neutral main wire near the lug should result in a reading at or above .05 on the meter, i.e., ten amps on the meter at the neutral main = 10 X .005 = .05 on the Tune Products™ leads MINIMUM *more current flowing through the Tune Products™ is better*).
- Complete the installation by replacing the electrical box/load panel cover and door.
- Restore power to the electrical box/load panel.

Device Realization and Function

The Tune Products™ is an assembly of two specialized inductors connected in the electrical circuits' return path, known as the neutral.

If the Tune Products™ is a filter for current outside the fundamental frequency of 60Hz, what does it do with the harmonic currents? The Tune Products™ operates similarly to power factor correction capacitors for lagging power factor inductive loads. They provide power factor correction for leading power factor loads with capacitive profiles. Power factor correction capacitors, connected from phase to phase, correct the power factor on inductive loads back to the unity power factor. In contrast, an inductor, connected in the neutral return path of the circuit, corrects the power factor on leading power factor type loads. In their quest for miniaturization, the manufacturers of power supplies and drivers have developed transistorized power supplies using switching techniques known as "PWM" with capacitors connected to the line side, which could either be 277 VAC, 120 VAC, or 240 VAC. This technique replaced the large inductor in the power supply and facilitated miniaturization. This turning off and on of transistors inside power supplies has two side effects: a leading power factor effect on the "hot" and neutral conductor feeding them and inserting harmonics into those same two conductors. The harmonics are a multiple (3x,5x,7x,9x,11x, etc.) of the 60Hz waveform provided on the "HOT" by the utility company. The harmonics from each one of these "hot" and neutrals in a panelboard generate some heat because of the energy displayed on the circuit's current and voltage waveforms. The inductor within the TUNE PRODUCTS™ performs the same function that any other inductor in a dry type of transformer would perform: "absorbs" the energy associated with these harmonics and dissipates it within the panel board.

Simply put, the TUNE PRODUCTS™ inductor is the addition of the inductor that was in the power supply circuit to begin with before miniaturization. Electrically, it is connected to the "return" circuit of the power supply by adding it to the neutral assembly. The ETL rating has said it is safe to dissipate this heat under the UL standard for filters commonly known as U.L. 1283.

Insulated Coil Inductance

The inductance of the insulated coil assembly can be computed as follows, given the diagram below and the fact that the coil's core is normal air with a magnetic permeability of μ_0 or 4π x 10^{-7}. We see this is a 14-turn solenoid.

Note: dimensions are converted to SI units for the sake of simplicity.

$$L=\frac{u N^2 A}{l}$$

$$L=\frac{(4\pi 10^{-7})(14)^2(\pi)(.00789)^2}{.0525}$$

$$L=.92\ \mu\text{Henry}$$

This value has been verified by independent laboratory testing (lab report from Pulse Electronics)

Specialized Coil Circuit Inductance

The inductance of the coil assembly is computed similarly. However, in the case of the primary inductor coil, a larger µ must be used than μ_0 due to the increased magnetic permeability of the specialized core. Several factors complicate the computation of the inductance of the uninsulated coil. The proprietary core of the bare coil is conductive and ferromagnetic in nature but does not suffer from eddy currents like most ferromagnetic cores. The conductive nature of the core, the hysteresis effects, and dependence on the B field of the magnetic permeability drive the computing of this coil's inductance beyond the scope of this writing. However, Pulse Electronics testing has shown it to be 1.95 to 2.0µHenry depending on current and frequency. The Pulse Electronics design diagram (PA3583NL) is the image of the inductor built with a unique core metal designed to impact only current above 100Hz.

Mutual Inductance

The total series inductance of the Tune Products™ has been measured to be 2 to 8 milli-Henry (depending on the model) at the operating frequency of 60Hz with very low current. Given the placement of the coils, their direction and proximity, and the fact that the individual coils in series can only account for 50% of the series inductors, it is highly likely that mutual inductance is a factor in the operation of the device. The magnitude and impact of mutual inductance within the device will be calculated in future revisions of this paper.

Other Stray Inductances and Capacitances

As Tune Products™ only uses solid core wire for internal circuit board connection to solid copper leads, no significant stray inductances or capacitances are present, even with connecting leads up to two meters each. The installer is responsible for minimizing the risk of inducing current into the Tune Products™.

Representative Series Resistance

Without leads required for installation, the Tune Products™ inductive baseplates are attached to 12 AWG copper wires with a resistivity of 5.208mΩ/Meter at the operational frequencies of the device. The standard installation leads are 18 inches long, each of 12 AWG copper wires with a resistivity of 5.58mΩ/Meter. Thus, the total series resistance can be represented as follows:

R= .457Meters@5.208mΩ/Meter = 2.38mΩ

Note: Increasing the installation lead length has been shown to decrease the efficacy of the Tune Products™ due to increasing the representative series resistance and reducing the current flow through the device.

Next Generation:
The Tune Heavy Commercial

Continuous improvement strategies have driven additional discoveries. By making some changes, several improvements have expanded the body of knowledge and created a positive impact with next-generation Tune Products™ technology.

By exchanging the existing inductor with a much more powerful inductor, performance measurements between September 2018 and September 2019 indicate that the impact of the inductive filter can be increased in several areas:

1. Additional reduction in KWH above the savings provided by the Tune Products™.
2. Additional reduction in peak demand charges beyond those provided by the Tune Products™.
3. Ancillary improvements in facility power quality have reduced 'repair/replace' and maintenance expenses.

These changes include doubling the inductance rating of the primary inductor (increasing from 6 milli-Henries to 12 milli-Henries), replacing the external air coil inductor with an internal, board-mounted air coil inductor (increasing the inductance from 1 to 1.75 millihenries); and by replacing the external air coil with an inner board mounted coil, the leads of the filter were exchanged from solid 12 AWG copper wire to stranded 12 AWG copper wire (thereby expanding the 'skin effect' and increasing the amount of current flowing through the filter.

Tested at a fast-food restaurant after using the Tune Products™ for a year, where savings ranged from 5% to 7%, the T12 increased KWH savings, peak period savings, and further reduced repair and replace costs to 5 franchise locations. Savings with the T12 are in the 7 to 9% range with 20% higher peak period savings.

A library had used the Tune Products™ for 18 months and was experiencing savings above 20%. When the Tune Products™ were replaced with the Tune Heavy, the savings increased by an additional 20%.

A pumping station had installed the Tune Products™ for 18 months and reported savings of 10% over prior years without the Tune Products™. When the Tune Products™ were replaced with the T12, these savings increased by another 25%.

Tested at a grocery store chain saw KWH savings increase from 4.5% to almost 6% per month when the Tune Heavy was installed (a 25% increase).

These results have been independently verified, and the facilities have normalized for any temperature variations.

TESTING with Secondary Transformers –2017

Meeting Objective: Test the T-7 (inductive transformer filter) assembly installed in parallel on the neutral bus and determine the energy savings (KW) and reduction of Total Harmonic Distortion when secondary transformers are within 10 feet of the sub-panel where the Tune Products™ is installed.

Environment: Controlled Lab setting in PA, 74°F, 40% humidity

Overview:

- The tests were conducted using a 208Y/120-volt panel fed from a standard 220°C, H 150°C rise vacuum impregnated dry type transformer rated 480 VAC primary, with a 208Y/120 VAC secondary and a
- 5.75% impedance. The 20 amperes, one pole branch breakers panelboard provided power to switching power supplies loaded by resistive elements.
- The meter used to monitor and log findings was a Fluke 435. It was used to monitor the load and neutral currents.
- The initial test involved disconnecting the double-stacked neutral bar (mounted below the panelboard's main breaker) and reconnecting it linearly with the use of # 6 AWG RHHN/RHHW conductor.

- A 20 ampere, one pole circuit breaker was connected in series with the T-7 to demonstrate with and without the T-7 protection.
- A total harmonic Distortion waveform of 39% was injected into the panelboard across all three phases with a total of 12.23 KW, a displacement power factor of .99, and a power factor of .70.
- There was no change in the correction of either the power factor or the reduction in the THD.
- The test was moved to the 208Y/120 VAC panelboard that provides power to the neutral-connected LED lighting and the inverters that charge the Lithium-Ion batteries. This was a 10.3 KW load with a THD of 23%. There was no appreciable reduction with the T-7 in the circuit for either THD or power factor.
- It was noted that the neutral current through the T-7 increased as the three phases, A, B, & C became more unbalanced. An increase in the 3rd harmonic on any phase also increased the current through the T-7.

<u>Administrative Overview, Preliminary Conclusions, and Next Steps following the test.</u>

Because the impedance (5.75%) of the dry type of transformer, mounted within 10 feet of the load, the impact on savings of the T-7 (impedance rating 3.5 to 4%) on the secondary transformer in this test set were negligible. (When doing an installation audit for the adoption of the Tune Products™, diligence is required to ensure that no dry-type secondary transformers with impedance ratings above 5% and located within 10 feet of the sub-panel are already servicing the subpanel(s).)

NOESIS and CHI Energy Services Reports

The following third-party engineering reports were conducted using IPMVP and ASHRAE 14 standards according to DOE guidelines for whole-building analysis. The reports were conducted over extended periods, the details of which are available upon request.

Noesis

PROJECT	LOCATION	BUILDING TYPE/SIZE(S)	SAVINGS
Krystal Stores	Atlanta, GA	Fast Food 1800 Sq Ft	10+%
Buffalo Rock Distributing	Birmingham, AL	Office & Warehouse 175,000 Sq Ft	15.2%
Corey Advertising	Atlanta, GA	Office 15,000 Sq Ft	8%

CHI Energy Services

PROJECT	LOCATION	BUILDINGTYPE/SIZE(S)	SAVINGS
Caribe Resorts	Orange Beach, AL	200+ Condo complex -common area 30,000 sq ft -30,000sqft	18.7-23%
Serra Mazda	Birmingham, AL	Auto dealership	11.5%
Taco Bell – 10 Stores	Birmingham area, AL	Fast food – 2,200 sq ft	10.8 to 14%
Inverness Country Club	Birmingham, AL	Country Club, kitchen, pro room, dressing area, ball rooms	14%
Planet Fitness	Birmingham, AL	Gym – 10,000 sq ft	13%
DC Oil	Brent, AL	Convenience Store	14%
Jacksonville Reg Medical Center	Anniston, AL	3 story 50 bed hospital	Above 10%
Owensboro Medical	Owensboro, KY	Health Park -155,000 sq ft with pool, gym, rehab, kitchen, offices, basketball court	12.9%
Owensboro Medical	Owensboro, KY	Business Service Center 44,000 sq ft – Converted A&P Store to Business Center	12.2%

Background References

Oak Ridge National Labs: 1999 "Costs and Benefits of Harmonic Current Reduction for Switch-Mode Power Supplies in a Commercial Office Building" Thomas **S.** Key, *Senior Member, IEEE,* and Jih-Sheng Lai, *Senior Member, IEEE*

IEEE Vol 32 #5 Sept/Oct 1996 Costs and Benefits of Harmonic Current Reduction for Switch-Mode Power Supplies in a Commercial Office Building Thomas **S.** Key, *Senior Member, IEEE,* and Jih-Sheng Lai, *Senior Member, IEEE*

Engineering and Construction Magazine (ECM) – LED Lighting and Power Quality, (3-part series) 12-2017 thru 1-2018

Electrical Product Research Institute (EPRI)

Schneider through SquareD (1997) "Origin, Effect, and Suppression of Harmonics"**; Bulletin 0140PD9502**

Eaton Corp: PowerWare White Paper: "On three-phase branch circuits, instead of installing a multi-wire branch circuit sharing a neutral conductor, run separate neutral conductors for each phase conductor. This increases the capacity and ability of the branch circuits to handle harmonic loads. This approach successfully eliminates the addition of the harmonic currents on the branch circuit neutrals, but the panelboard neutral bus and feeder neutral conductor must still be considered."

Trane Engineering Newsletter, 2019: "Be aware of Harmonics in the Power Systems…"

Dataforth Corp Application Note (AN129) "Harmonics and Utility Costs"

Harmonics Limited: "Eliminating Harmonics Neutral Current Problems" – Michael Lowenstein PHD

Pacific Gas and Electric – 2007 – "Economics of Power Factor Correction in Large Facilities"

Additional References:

1. Electrical Transmission and Distribution Reference Book, 4th edition, 1950, Westinghouse
2. Electric Corporation, chapter 8, Application of Capacitors to Power Systems.
3. IEEE Standard 1531-2003 Guide for Application and Specification of Harmonic Filters.
4. IEEE Standard 1459-2000 Trial Use Standard for Standard Definitions for the
5. Measurement of Electric Power Quantities Under Sinusoidal, Non-Sinusoidal, Balanced,
6. or Unbalanced Conditions.

i. IEEE/IAS Costs and Benefits of Harmonic Current Reduction for Switch-Mode Power

7. Supplies in a Commercial Office Building, IEEE Transactions on Industry Applications,
8. Vol.32, No.5, September/October 1996.

i. IEEE Standard 141-1993, Recommended Practice for Electrical Power Distribution for

9. Industrial Plants. Chapter 8, Power Factor and Chapter 9, Harmonics in power systems.
10. This publication is also known as the Red Book.

i. IEEE Standard C57.110-1998, Recommended Practice for Establishing Transformer

11. Capability When Supplying Nonsinusoidal Load Currents.

i. R.C. Dugan, M.F. McGranaghan, S. Santoso, and H. W. Beaty, *Electrical Power Systems*

12. *Quality*, Second Edition, McGraw-Hill, Professional Engineering Series, New York, 2003.

Tune Impact on LED Lighting

Introduction

Multiple articles have been written over the past ten years highlighting the issues and problems created when electronics, particularly computers, switch-mode power supplies, and LED lights (Light Emitting Diodes), are introduced into electric systems. (A partial list of articles reviewed by this author is attached at the end of this document). Basically, the articles highlight the associated impact on power quality for architects, facility managers, maintenance managers, electrical engineers, and electricians. All the articles agree that LED lighting systems reduce electric consumption and result in a reduction of KWH usage as well as the associated cost.

In EC&M (ecmweb.com), Phillip Keebler, Electrotek Concepts, Inc. (Nov 2017) states, "As the number and power level of electronic loads increases in industrial and commercial facilities, the probability of malfunction and failure of LED lighting also increases. Consider what is happening to the designs of electronic loads like variable-frequency drives (VFDs) and electronic power supplies used in production equipment, computers, and servers. While energy efficiency is increasing, power levels are also increasing. What else is increasing? The switching frequencies of power electronics switching devices are increasing to help achieve higher energy efficiencies. Higher switching frequencies and better devices with lower switching losses mean their turn-off/turn-on times also increase. If internal filtering – both around the power switches and in the AC input network – in these electronic loads is not improving quickly enough, then transients with faster rise times with increased frequencies generated by the operation of larger electronic loads are more threatening to end-use equipment like LED lighting than they were in older equipment. (p15)."

Most of these articles further conclude that the power factor of LED lighting is between 35 and 65% and that they introduce harmonic currents into the electric system of a building. They point out that the higher cost of LED lights should be offset by the 50,000+ hours that they are designed to operate; however, the harmonic currents that LEDs are subjected to can reduce the savings of the LED lights (by generating additional heat that reduces the useful life).

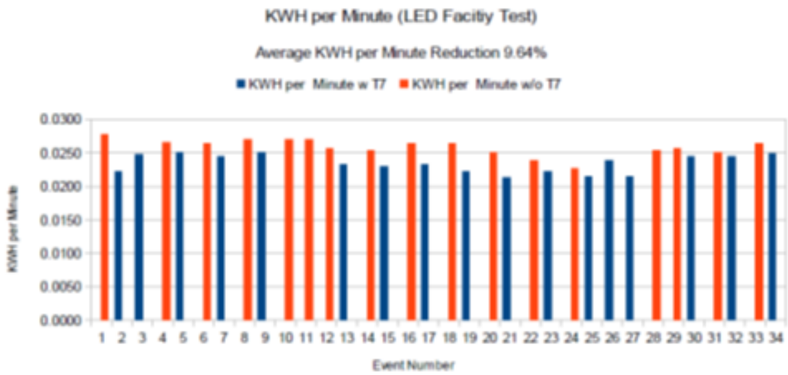
This paper aims to expand upon the solutions offered by the esteemed authors of these articles by adding another low-cost, low-risk, passive, inductive, harmonic-reducing filter to the solutions that are otherwise mentioned. Several articles refer to the benefit that users can receive by installing a 'passive inductive filter' in the load panels closest to the loads generating the harmonics. These articles maintain that moving that filter to the leading power distribution equipment will negate the benefit.

In studies conducted and overseen by the author over the past eight years in different residential, commercial, and government buildings across the US, the studies have shown a reduction in total harmonic distortion by installing a harmonic filter in the electric load panel has helped customers achieve benefits that include: 1) reduction in KWH usage; and 2) reduced equipment maintenance and repairs.

a. ‘Cabin Case Study’ – 88 incandescent and CFL lights were replaced with 88 LEDs

Tune impact on LED Lighting installation

The first test, prior to installing LED lights, measured 10 KWh electricity used in 3 hours by these loads.
When the LED lights were installed, the second test measured 5 KWh used in 3 hours.
Tune Filter was installed and the third test measured 4 KWh used in 3 hours.
Proof of concept was established and more refined testing was begun. The outcome is presented graphically below. Multiple tests on multiple days, both weekdays and weekends, were run to collect the data.



Tune LLC - Presentation For Engineers 9

b. **'Rainsville AL Case Study'**

In the graph below was presented to the Mayor and City Council members for the City of Rainsville, AL in June 2018. The project conducted by the Mayor and County Commissioners for the City of Rainsville, AL was to upgrade the lights to LED lights to achieve electric savings of 25% and include an electric (TUNE) harmonic filter with each load panel installation to reduce harmonics created by the LED lights and other electronic loads in the city. As of this writing, not a single light bulb or fixture has been replaced since the projection inception in 2018.

The 2 largest users of electricity in the city are the Pumping Station (replaced inductive pumps/motors with VFDs) and the Agri Center. Neither of these facilities were included in the LED retrofit and filter project. Savings were projected on the buildings to exceed 25% and that goal was achieved. (The analysis below does not include all buildings and all installations, only those made available for this analysis.)

Building	Meter	2017 KWH	2019 KWH	Avg Savings	4 years KWH Saving
City Hall	800081	35,750	27,500		33,000
Police Dept	325063	67,350	56,400		43,800
Library	700009	75,250	56,414		75,344
Field of Dreams	375032	21,900	5,475		16,000
Field of Dreams 2	101354	20,075	6,550		54,100
TBEC	325092	79,860	35,510		177,400
Welcome Sign 75N	102062	1,460	365		4,380
Welcome sign	114533	1,300	365		3,740
Welcome Sign 35E	113752	1,240	365		3,500
Lions Club	101399	9,415	8,200		4,860
subtotal		313,600	197,144	37%	
NE Agri Center	875053	382,000	320,000	16%	124,000
Pumping Station	875042	960,000	867,000	10%	372,000
Totals		1,655,600	1,384,144	16.3%	912,124

c. **Commercial Office Building 'Instantaneous Impact Measurement Study'**

Panel HPN1 (480/277V) - No Tune with Tune

No Tune		Tuned	
Source File:	Ucare_NoTune	Source File:	UCare_With_Tune
Test Began:	8/22/22 at 10:41:00	Test Began:	8/22/22 at 11:55:00
Test Ended:	8/22/22 at 11:01:00	Test Ended:	8/22/22 at 12:15:00
Data Source:	PowerSight PS5000, SN 50064	Data Source:	PowerSight PS5000, SN 50064

Measurement	No Tune	Tune	Units	Change	% Change
Voltage, V1x, Avg	275.3	275.9	volts	0.6	0.23%
Voltage, V2x, Avg	277.6	278.4	volts	0.8	0.28%
Voltage, V3x, Avg	275.6	276.2	volts	0.7	0.25%
Current, Phase 1, Avg	73.3	64.4	amps	-8.9	-12.13%
Current, Phase 2, Avg	52.8	37.4	amps	-15.4	-29.23%
Current, Phase 3, Avg	110.8	101.5	amps	-9.3	-8.37%
Current, Neutral, Avg	66.7	62.1	amps	-4.5	-6.78%
True Power, Total, Avg	62.586K	54.277K	Watts	-8308.3	-13.28%
VA Power, Total, Avg	65.359K	56.213K	VA	-9146.6	-13.99%
Unbalanced Voltage Ph-N, Total, Avg	0.5	0.5		0.0	2.78%
Unbalanced Current, Total, Avg	42.6	49.8		7.2	16.97%
THD Voltage, Phase 1, Avg	3.4	3.4	%	-0.0	-1.42%
THD Voltage, Phase 2, Avg	3.4	3.3	%	-0.0	-1.09%
THD Voltage, Phase 3, Avg	2.7	2.7	%	-0.1	-2.32%
THD Current, Phase 1, Avg	22.4	19.3	%	3.1	-13.80%
THD Current, Phase 2, Avg	33.3	23.4	%	10.0	-30.1%
THD Current, Phase 3, Avg	21.0	20.8	%	-0.3	-1.30%
THD Current, Neutral, Avg	52.4	36.4	%	-16.1	-30.64%

Measurement	No Tune	Tune	Units	Change	% Change
Energy, Phase 1 Elapsed:	5.8	5.5	KWh	-0.4	-6.23%
Energy, Phase 2 Elapsed:	3.9	3.0	KWh	-0.9	-22.89%
Energy, Phase 3 Elapsed:	8.9	8.7	KWh	-0.2	-2.31%
Energy, Total Elapsed:	18.6	17.2	KWh	-1.5	-7.82%
VAH, Phase 1 Elapsed:	6.0	5.6	KVAh	-0.4	-6.38%
VAH, Phase 2 Elapsed:	4.3	3.3	KVAh	-1.0	-23.99%
VAH, Phase 3 Elapsed:	9.1	8.9	KVAh	-0.2	-2.61%
VAH, Total Elapsed:	19.5	17.8	KVAh	-1.7	-8.53%
VARH, Phase 1 Elapsed:	1.4	1.3	KVARh	-0.1	-8.89%
VARH, Phase 2 Elapsed:	1.9	1.4	KVARh	-0.5	-28.08%
VARH, Phase 3 Elapsed:	1.9	1.7	KVARh	-0.2	-8.78%
VARH, Total Elapsed:	5.5	4.6	KVARh	-0.9	-16.05%
Energy, estimated per month:	45.687K	39.622K	KWH	-6065.0	**-13.28%**

Harmonics for In (change on Neutral Measurements without and with Tune – Commercial 480/277 LED Lighting test)									
Harmonic #	No Tune % (Avg,Max,Min)			With Tune % (Avg,Max,Min)			Change % (Avg,Max,Min)		
1:	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0
3:	52.6	79.0	35.0	35.2	36.0	35.0	-17.4	-43.0	0.0
5:	3.8	7.0	2.0	2.6	3.0	2.0	-1.2	-4.0	0.0
7:	4.6	5.0	4.0	4.6	5.0	4.0	0.0	0.0	0.0
9:	3.6	6.0	2.0	2.2	3.0	2.0	-1.4	-3.0	0.0
11:	0.6	1.0	0.0	0.7	1.0	0.0	0.0	0.0	0.0
13:	0.8	1.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0
15:	2.9	3.0	2.0	3.1	4.0	3.0	0.0	1.0	1.0
17:	1.4	2.0	1.0	1.8	2.0	1.0	0.0	0.0	0.0
19:	0.0	1.0	0.0	0.8	1.0	0.0	0.0	0.0	0.0
21:	3.8	4.0	3.0	3.8	5.0	3.0	0.0	1.0	0.0
23:	0.8	1.0	0.0	0.7	1.0	0.0	0.0	0.0	0.0
25:	1.0	1.0	1.0	1.1	2.0	1.0	0.0	1.0	0.0
27:	2.0	3.0	1.0	2.0	2.0	2.0	0.0	-1.0	1.0
29:	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
31:	0.0	1.0	0.0	0.8	1.0	0.0	0.0	0.0	0.0
33:	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
35:	0.9	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
37:	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0

Conclusions

By installing a passive, inductive, transforming TUNE filter into the load panels closest to the loads generating harmonic currents, a measurable reduction in harmonics has been measured. A measured reduction in KWH has been consistently recorded. A measured reduction in repair and replace costs has been measured.

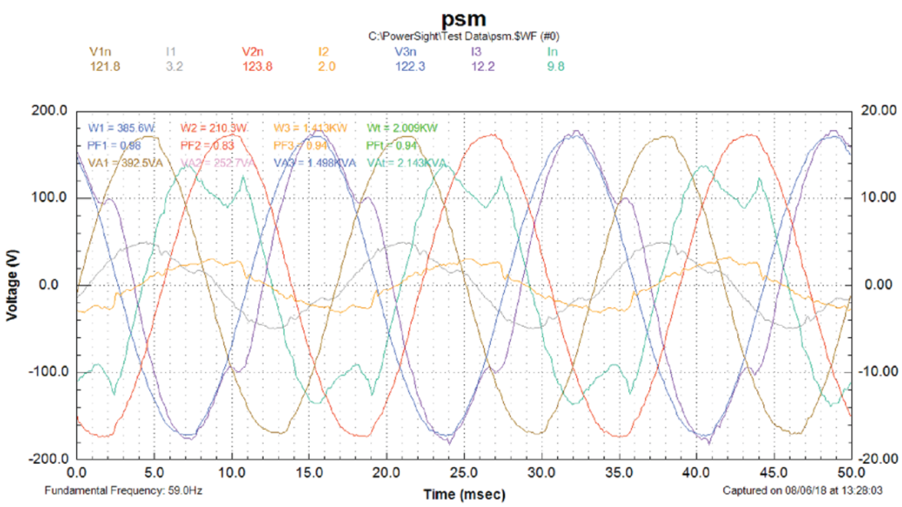
Harmonics Currents on Neutral (In) comparison – No Tune compared to Tune T7 – 208V/120V panel									
Harmonic #	**Before % (Avg,Max,Min)**			**After % (Avg,Max,Min)**			**Change % (Avg,Max,Min)**		
1:	100.0	100.0	100.0	44.4	100.0	0.0	-55.6	0.0	-100.0
3:	4.8	13.0	2.0	1.4	4.0	0.0	-3.3	-9.0	-2.0
5:	6.3	13.0	0.0	0.0	1.0	0.0	-5.9	-12.0	0.0
7:	6.9	12.0	2.0	0.0	1.0	0.0	-6.8	-11.0	-2.0
9:	4.8	9.0	0.0	0.0	0.0	0.0	-4.8	-9.0	0.0
11:	2.6	9.0	0.0	0.0	0.0	0.0	-2.6	-9.0	0.0
13:	1.8	5.0	0.0	0.0	0.0	0.0	-1.8	-5.0	0.0
15:	2.6	9.0	0.0	0.0	0.0	0.0	-2.6	-9.0	0.0
17:	0.0	3.0	0.0	0.0	0.0	0.0	0.0	-3.0	0.0
19:	2.8	6.0	0.0	0.0	0.0	0.0	-2.8	-6.0	0.0
21:	0.9	4.0	0.0	0.0	0.0	0.0	-0.9	-4.0	0.0
23:	0.7	4.0	0.0	0.0	0.0	0.0	-0.7	-4.0	0.0
25:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27:	0.9	4.0	0.0	0.0	0.0	0.0	-0.9	-4.0	0.0
29:	0.6	3.0	0.0	0.0	0.0	0.0	-0.6	-3.0	0.0
31:	0.0	3.0	0.0	0.0	0.0	0.0	0.0	-3.0	0.0
33:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39:	0.0	2.0	0.0	0.0	0.0	0.0	0.0	-2.0	0.0
41:	0.0	2.0	0.0	0.0	0.0	0.0	0.0	-2.0	0.0
43:	0.0	4.0	0.0	0.0	0.0	0.0	0.0	-4.0	0.0
45:	1.2	3.0	0.0	0.0	0.0	0.0	-1.2	-3.0	0.0
47:	0.0	4.0	0.0	0.0	0.0	0.0	0.0	-4.0	0.0
49:	0.7	3.0	0.0	0.0	0.0	0.0	-0.7	-3.0	0.0

Appendix 4

Tune and SOLAR Installations

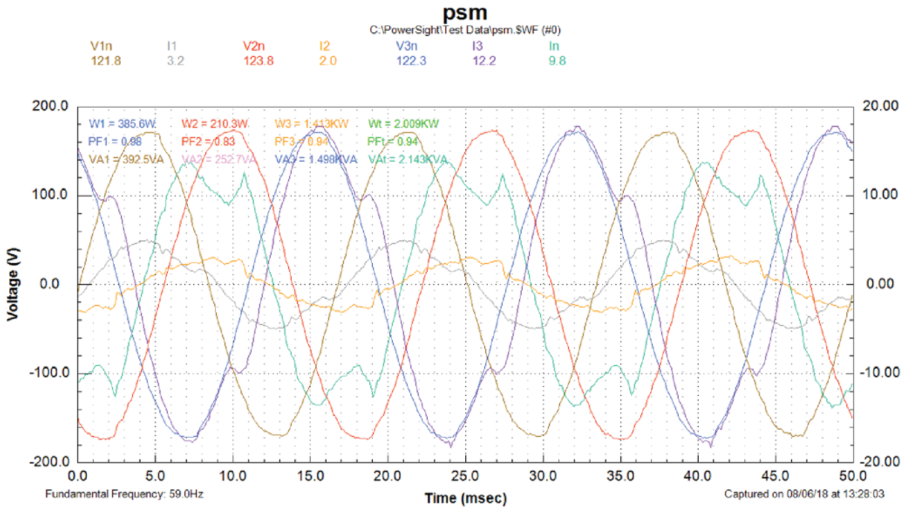
- Tune has done multiple installations in concert with solar homes but never had the opportunity to study the details of the data…and the anecdotal reports (limited review of the data) that came from the solar installations ranged from an additional 10 to 15% savings after installation. Derrick would let us connect our Power Sight 2500 meter (from Summit Technologies) at current software revision levels and recent calibration.
- Derrick is the solar homeowner in a rural area of South Carolina near Anderson.
- A solar design firm (Aaron Davis of Firefly Solar) installed 36 panels on the roof, feeding four separate TESLA lithium-ion batteries. The batteries combine to provide 240 volts to a single-phase 200Amp load service panel that supports the home's AC power demands.
- If the battery drops in charge (because the sun doesn't shine enough to charge them), a standby 20KVA Kohler generator is served by a 1,000-gallon propane tank. If the generator kicks on, it charges the batteries.
- The batteries feed the house, which has 2,500 square feet of living area and 5,000 square feet of workshops, garages, and undercover space.
- (Note: In the first season, the homeowner observed that the heat pump drained the batteries rapidly during the cold of winter and decided to add a wood stove to reduce the heat load on the electric system.)

Data Collection Before Tune® Installation.



Measurement	Value	Units
Voltage, Phase 1, Avg:	122.1	volts
Voltage, Phase 2, Avg:	119.4	volts
Current, Phase 1, Avg:	31.1	amps
Current, Phase 2, Avg:	47.9	amps
Current, Neutral, Avg:	21.3	amps
Current, Neutral, Max:	24.8	amps
Current, Neutral, Min:	20.0	amps
Power Factor, Phase 1, Avg:	0.98	
Power Factor, Phase 2, Avg:	0.97	
True Power, Phase 1, Avg:	3.729K	Watts
True Power, Phase 2, Avg:	5.573K	Watts
VA Power, Phase 1, Avg:	3.798K	VA
VA Power, Phase 2, Avg:	5.719K	VA
VAR Power, Phase 1, Avg:	719.6	VAR
VAR Power, Phase 2, Avg:	1.286K	VAR
Frequency, Avg:	59.7	Hz
THD Current, Phase 1, Avg:	16.0	%
THD Current, Phase 2, Avg:	13.0	%
THD Current, Neutral, Avg:	11.0	%

Data Collection Following Tune® Installation.



Measurement	Value	Units
Voltage, Phase 1, Avg:	122.2	volts
Voltage, Phase 2, Avg:	119.1	volts
Current, Phase 1, Avg:	35.3	amps
Current, Phase 2, Avg:	58.8	amps
Current, Neutral, Avg:	22.4	amps
Current, Neutral, Max:	25.1	amps
Current, Neutral, Min:	20.6	amps
Power Factor, Phase 1, Avg:	0.99	
Power Factor, Phase 2, Avg:	0.99	
True Power, Phase 1, Avg:	4.259K	Watts
True Power, Phase 2, Avg:	6.910K	Watts
VA Power, Phase 1, Avg:	4.316K	VA
VA Power, Phase 2, Avg:	7.000K	VA
VAR Power, Phase 1, Avg:	696.4	VAR
VAR Power, Phase 2, Avg:	1.116K	VAR
Frequency, Avg:	59.7	Hz
THD Current, Phase 1, Avg:	10.8	%
THD Current, Phase 2, Avg:	9.0	%
THD Current, Neutral, Avg:	6.0	%

Pre and Post Installation Comparison

Total Harmonic Distortion (THD) Reductions:

- 30%+ on Hot Phases
- 45%+ on Neutral

Measurement	Before	After	Units	Change	%Change
Voltage, Phase 1, Avg:	122.1	122.2	volts	0.05	0.04%
Voltage, Phase 2, Avg:	119.4	119.1	volts	-0.25	-0.21%
Current, Phase 1, Avg:	31.1	35.3	amps	4.22	13.57%
Current, Phase 2, Avg:	47.9	58.8	amps	10.86	22.68%
Current, Neutral, Avg:	21.3	22.4	amps	1.06	4.95%
Current, Neutral, Max:	24.8	25.1	amps	0.26	1.03%
Current, Neutral, Min:	20.0	20.6	amps	0.57	2.83%
Power Factor, Phase 1, Avg:	0.98	0.99		0.01	1.02%
Power Factor, Phase 2, Avg:	0.97	0.99		0.02	2.06%
True Power, Phase 1, Avg:	3.729K	4.259K	Watts	529.80	14.21%
True Power, Phase 2, Avg:	5.573K	6.910K	Watts	1.337K	24.00%
VA Power, Phase 1, Avg:	3.798K	4.316K	VA	517.60	13.63%
VA Power, Phase 2, Avg:	5.719K	7.000K	VA	1.281K	22.39%
VAR Power, Phase 1, Avg:	719.6	696.4	VAR	-23.22	-3.23%
VAR Power, Phase 2, Avg:	1.286K	1.116K	VAR	-169.61	-13.19%
Frequency, Avg:	59.7	59.7	Hz	0.40m	0.67m%
THD Current, Phase 1, Avg:	16.0	10.8	%	-5.25	-32.81%
THD Current, Phase 2, Avg:	13.0	9.0	%	-4.00	-30.77%
THD Current, Neutral, Avg:	11.0	6.0	%	-5.00	-45.45%

Trane Corporation

Roanoke, VA Energy Project Analysis

Parts Depot – R2 value (confidence factor .95) - Dominion Power

- Average KWH Reduction to date: 13%

Sales Office – R2 value (confidence factor .81) - Solar Power and Dominion Power

- Average KWH Reduction to date: 12%