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Energy waste you didn't even know about. Do you care?

Several years ago, most facilities viewed their monthly electrical utility bill as a standard cost of doing business. When oil topped $100 per barrel, attitudes changed practically overnight, generating a surge of interest in energy-conscious retrofits that previously would not have been cost-effective. Yet, when the energy costs came down, attitudes and practices did not entirely revert. The United States was still trying hard to shake a recession. Global competition for providing products and services had grown even more intense. American facilities had found a potential new source for margin and profitability improvement in the form of their monthly energy bill, and they weren't giving it up.

At the same time, utilities in the United States began customer service campaigns aimed at helping facilities make better use of the power they were consuming. Why would a utility want to help customers lower their bill? Because capacity is limited. Given the regulatory framework, length of project time, and sheer cost to build new power-generation facilities, utilities have a vested interest in extending the reach of their existing generation capacity. To keep adding new customers to the grid, existing customer usage has to be optimized. Oil platform and nuclear meltdown disasters have only served to underscore how limited the options are.

In the last five years, most mid-sized facilities have been tutored by their electrical utility on how to fully understand their monthly statement and have possibly done a basic energy audit, to determine which operational functions consume how much energy per month. Many facilities have identified the 'low-hanging fruit', which is available to be harvested: In other words, energy consumption that can be decreased without substantial investment. Common examples include: shutting off equipment and systems overnight instead of leaving them on, taking advantage of government energy-efficiency subsidies, upgrading lighting systems and large loads like chillers to high-efficiency models, fixing leaks in compressed air lines, adding controls to match mechanical equipment outputs to performance requirements.

What's an energy audit?

While ASHRAE identifies four levels of energy audits, level 0 and level 1 audits are the most popular as they simply require comparison with benchmarked consumption rates at other similar facilities or conducting a facility walk-through, to visually identify energy savings opportunities. Common tactics include identifying and optimizing the largest loads in the facility. The most obvious of these loads is lighting. Since many utilities offer rebates for lighting upgrades, the cost is often low and the payback time short.

IEEE Assessment

In parallel to all this, more than ten years ago the IEEE power quality standards body began an assessment of the academic work necessary to more accurately segment and quantify energy consumption in three-phase electrical systems. It had been known for many years that there were gaps in the mathematical model underlying classical three-phase power measurement calculations. In particular, the effects of reactive power, harmonics, and load unbalance were not considered in the classical methods used in most power quality and consumption monitoring.

At that point in time, harmonic distortion and load unbalance were viewed as imperfections in the purity of power that caused equipment performance issues, and in the case of power factor, diminished the usability of the distributed power. Quantifying the amount of power made unusable had never been considered. Harmonics and unbalance were troubleshooting concerns, not energy consumption issues. That is, until energy became a premium commodity.

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Why care how much power is affected by harmonics and load unbalance? Because we've generated and paid for it, but we can't use it.

If 100 kilowatts come into a facility and a portion of those kilowatts is made unusable by poor power quality, the facility is paying for 100 kW but only able to use 100 kW minus the wasted portion. If one could quantify the waste, and multiply it by the utility rate schedule, then it would be pretty clear whether the amount of waste was expensive enough to merit fixing the power quality issues.

The outcome of the IEEE effort was a new standard, IEEE 1459-2000, that went some way into enabling the calculation of waste due to power quality but in a very academic framework. Still missing was a clear definition of the physical quantity of power waste. Shortly after the new standard was issued, two professors at the University of Valencia in Spain set out to develop the math necessary to quantify power waste due to harmonics and unbalance issues.

Firstly, Professors Vincente Leon and Joaquín Montañana developed mathematical methods based on the recommendations of the IEEE1459-2000 standard that defined the sources of specific waste. Then, they developed a measurement instrument with a computing system that calculated what they described as Unified Power.

Their breakthrough Unified Power measurement method took the best aspects of the IEEE1459-2000 recommendations and calculated the energy wasting effects of reactive power, harmonics, and unbalance in the electrical system.

The Fluke Corporation learned about the breakthrough and approached the professors about a partnership. Together, Fluke engineers and the professors transitioned the science from an academic instrument into a Unified Power measurement feature and an Energy Loss Calculator, now available in a portable, handheld power quality analyzer. Both parties hold patents, for different aspects of the new capability.

How do harmonics waste power?

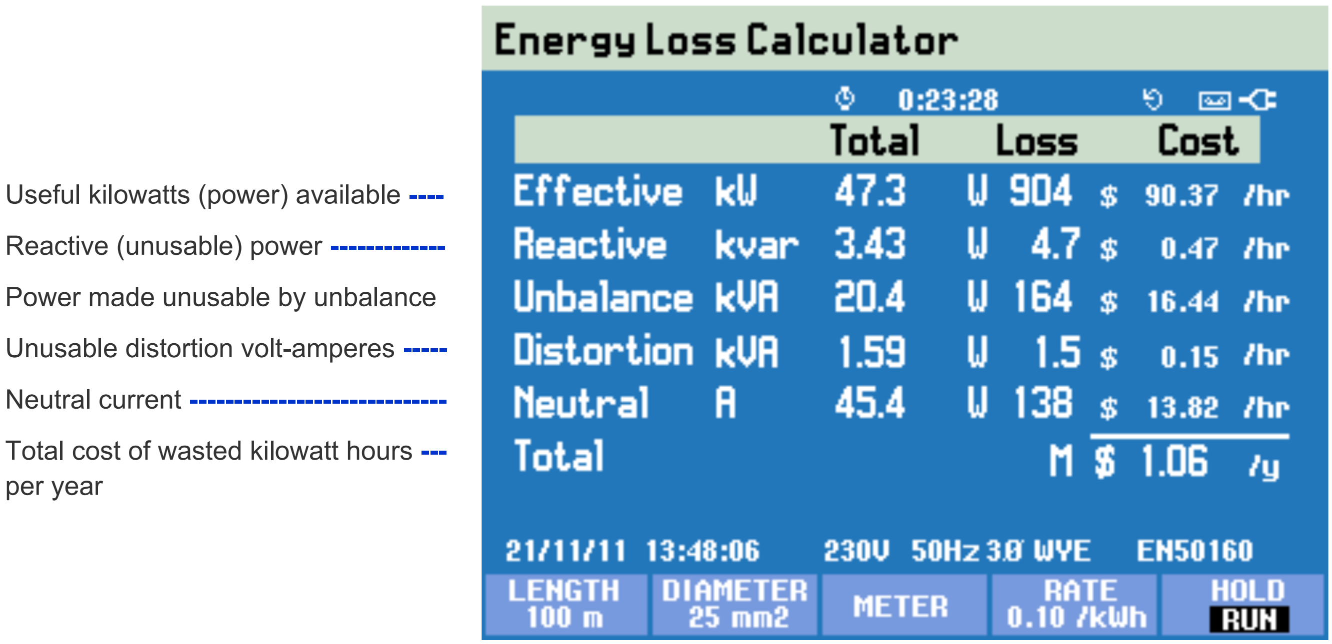
One of the most recognized effects of harmonics in electrical systems is the excess heat they create in the conductors carrying them. Many studies have identified the need to increase the size of neutral conductors in three-phase, four-wire distribution systems to compensate for high levels of third-order, zero-sequence harmonic currents. There are also documented cases of transformers overheating due to the presence of harmonics. That heat is a form of unintentional power-consumption. With this new method of calculation, it is possible to quantify the amount of waste in watts.

Why does load unbalance waste power?

In the case of three-phase motors, unbalance degrades unit performance and shortens their life spans. Voltage unbalance, at the motor stator terminals, causes phase current unbalance, far out of proportion to the voltage unbalance. Unbalanced currents, in turn, lead to torque pulsations, increased vibration and mechanical stresses, increased losses, and motor overheating. Each one of these effects consumes energy, now quantifiable in watts.

What is Unified Power?

The Unified Power measurement system uses a combination of classical methods, IEEE 1458-2010, and the University of Valencia's mathematical calculations to express power and energy measurements that directly quantify the waste energy in electrical systems. Unified Power measures harmonics and unbalance waste in terms of kilowatts, and by factoring in the cost of each kilowatt hour it's possible to calculate the cost of waste energy over a week, a month, or a year.



Field testing Unified Power – How much waste is there?

Professors Vincente Leon and Joaquín Montañana carried out multiple field studies to confirm their hypotheses about the link between power quality issues and the effect on energy waste. When Fluke joined the partnership, the team conducted more studies to test whether the new capability could be made usable to people outside of the highest-end electrical engineering professionals.

Two studies of particular note occurred at an industrial park and at an automotive manufacturing plant.

The industrial park is supplied by a local electrical cooperative. It's a mixed industrial park with a variety of electrical needs. Some of the park's customers had significant inductive loads and the utility had already chosen to install power factor correction to reduce the effects of the poor power factor. However, when the professor's Unified Power device was connected, it showed significant reactive power losses in the secondary of the power transformer in the park. The losses occurred primarily at night, when the inductive loads were not operating, but the power factor correction capacitors were. The energy losses were measured at 353.6 kWh per day (on average); multiplied by the utility's rate schedule this amounted to $14,000 per year. With this information in hand, the utility and the park manager devised a solution involving time-controlled relays that disconnected the capacitor bank at night. Payback time: less than one year.

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A study was also devised for a large automobile plant. Six separate areas of the plant were surveyed, and numerous causes of energy waste were identified across the plant, including reactive power from discharge lamps and lightly loaded, inefficient transformers. The total waste amounted to $50,000 per year. By installing power factor correction on the discharge lamps and rationalizing the transformer arrangement (by using one high efficiency transformer instead of five lightly loaded inefficient transformers), the plant achieved significant energy savings.

So, substantial energy really is being wasted by harmonics and unbalance.

What do you do about it?

Power Quality International, LLC has more than 50 years experience in *Power System Optimization.* Resolving power quality problems often involves the application of harmonic mitigation devices and/or the implementation of system alterations. Resolving unbalance may require re-distributing loads, installing unbalance compensation equipment or sometimes adjusting overall electrical distribution system capacity.

With the new Unified Power capability, costing out the labor and equipment necessary to abate the harmonics and unbalance, compared to the amount of energy wasted, is now a relatively straightforward ROI calculation.

Keep in mind that installing a harmonic filter will also improve overall power quality, increasing overall equipment reliability, efficiency, life span and decreasing downtime.

Based on our experience, however, the greatest overall savings often comes from improving voltage distortion at a system's loads (per IEEE Std 519). Voltage distortion increases load losses and reduces energy efficiency.

It used to be that you couldn't fix what you couldn't see. More recently, the adage might have been, you wouldn't fix what you couldn't justify. Now, seeing is believing.

Credit

Much of the foregoing information was provided by the Fluke Corporation.

Industrial park substation

$14,000 in annual energy savings from power quality adjustments

Measurements at the substation transformer feeding the industrial park identified energy losses of 353.6 kWh/day (average value) due to reactive power.

Solution: Install time-control relays to disconnect capacitor bank at night.

Automobile plant

$50,000 in annual energy savings

Surveys of six key areas including the engine plant and the car assembly plant showed significant energy waste due to power quality.

Solutions: Install capacitors and regulation controls and upgrade transformers.

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