What you haven't been able to see before now, probably has been biting you in a big way.

How things have changed. Seven years ago, most facilities still viewed their monthly electrical utility bill as a standard cost of doing business. When oil topped $100/barrel, however, attitudes changed practically overnight, generating a surge of interest in energy-conscious retrofits that previously would not have been cost-efficient. 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 of margin and profitability in the form of their monthly energy bill—*and they weren't giving it up*.

At the same time, utilities in the U.S. began customer-service campaigns aimed at helping facilities make better use of the power they were consuming. Why would a utility want to assist customers in lowering their bills? Answer: 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. If new customers are to continually be added 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 four years, most mid-range facilities have been educated by their electrical utilities on how to fully understand their monthly power bills—*and have possibly conducted a basic energy audit to determine which operational functions consume the most energy per month*

. Many sites have already identified “low-hanging fruit” available for harvest (i.e., means by which to cut energy consumption without substantial investment). Common examples of such “fruit” include shutting off certain equipment and systems overnight; upgrading lighting and large loads like chillers with high-efficiency equipment; taking advantage of government energy-efficiency subsidies; fixing leaks in compressed air lines; and adding controls to match mechanical equipment output to performance requirements.

For those with specific interests in electrical systems, though, the true costs of inefficiency had become an urgent matter much earlier. For example, 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 more than 10 years ago. Researchers had long recognized 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. Back then, harmonic distortion and load unbalance were simply 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 an energy- consumption issue—*until energy became a premium*

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Energy Audits

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

Why care about the amount of power affected by harmonics and load unbalance? Because we’ve generated and paid for it, but can’t use it.

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

The outcome of the IEEE efforts was a new standard—*IEEE 1459-2000*—that went some way toward enabling the calculation of waste due to power quality, albeit through a very academic framework. Still missing was a clear definition of the physical quantity of power waste. Shortly after the new standard was issued, Professors Vincente Leon and Joaquín Montañana, of Spain's University of Valencia, set out to develop the math necessary to quantify power waste due to harmonics and unbalance issues. They first devised mathematical methods based on the recommendations of the IEEE1459-2000 standard that defined the sources of specific wastes. Then, they created 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 recommendations and calculated the energy-wasting effects of reactive power, harmonics and unbalance in an electrical system.

Upon learning of Leon and Montañana's work, Fluke approached them 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 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 shown the need to increase the size of neutral conductors in power systems to compensate for high current carried in the neutral of 3rd harmonics and their multiples. 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, rather than heat.

Why load unbalance wastes power

In the case of three-phase motors, unbalance degrades unit performance and shortens service life. *Voltage unbalance* at the motor stator terminals causes a disproportionate (large) *phase current unbalance.*

Unbalanced currents, in turn, can lead to torque pulsations, increased vibration and mechanical stresses, increased losses and motor overheating. Each of these effects consumes energy, now quantifiable in watts.

How Unified Power technology works

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. The technology measures harmonics and unbalance waste in terms of kilowatts. As shown in the accompanying Energy Loss Calculator (Fig. 1), factoring in the cost of each kilowatt-hour makes it possible to calculate the cost of waste energy over a week, month or year.

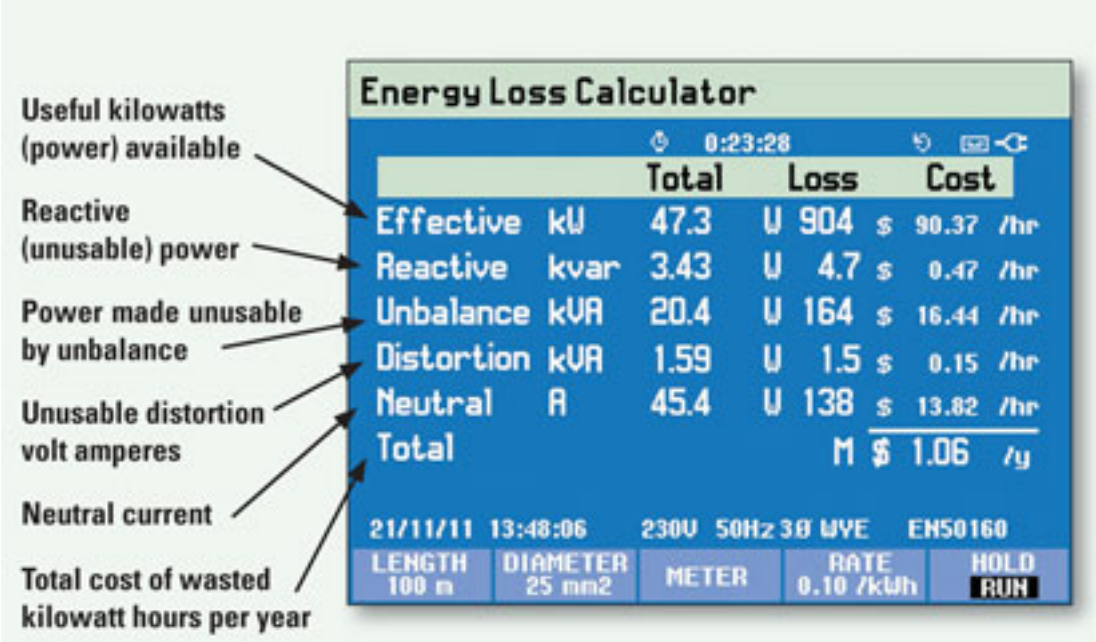

Fig. 1. The Unified Power system measures harmonics and unbalance waste in kilowatts. Factoring in the cost of each kilowatt-hour makes it possible to calculate the cost of waste energy over time.

Field-testing

How much energy waste is out there? Plenty. Professors Leon and 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 if the new capability would be appropriate for a range of users (i.e., other than those working in the highest-level electrical-engineering roles).

The studies included one at an industrial park and another at an automotive

manufacturing plant. . .

- The industrial park is supplied by a local electrical cooperative. Tenants in this mixed site had a variety of electrical needs. Some had significant inductive loads and the utility had already chosen to install power-factor correction to reduce the effects of poor power factor. When the professors' Unified Power device was connected, however, it showed significant reactive power losses in the secondary of the park's power transformer. 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/day (on average). Multiplied by the utility's rate schedule, these losses 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 was less than one year.

- At the automobile plant, six separate areas were surveyed. Numerous causes of energy waste were identified across the facility, 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, rationalizing the transformer arrangement and using one high-efficiency transformer instead of five lightly loaded, inefficient units, the plant achieved significant energy savings.

Dealing effectively with the waste factor

Addressing harmonics and unbalance typically requires the support of an electrical engineer and staff or contract electricians. Resolving harmonics involves some kind of mitigation equipment or changing the type of electronic equipment in operation. Resolving unbalance requires redistributing loads, installing unbalance compensation equipment or, sometimes, increasing 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 with the amount of energy wasted, is now a relatively straightforward ROI equation. Keep in mind that installing a harmonic filter will also improve overall power quality (which will increase equipment reliability, efficiency and service life and reduce downtime).

Yes, things really have changed in the way we approach energy efficiency: It used to be that you couldn't fix what you couldn't see—*or that you couldn't fix what you couldn't justify.* Now, seeing is believing, and the fixing is easy.

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Study Findings:

Industrial Park Substation: $14,000 in annual energy savings from power quality adjustments

- *Measurements at the substation transformer feed-ing 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.*

Automotive Manufacturing 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.*
- *Solution: Install capacitors and regulation controls and upgrade transformers.*

E-mail: frank.healy@fluke.com.