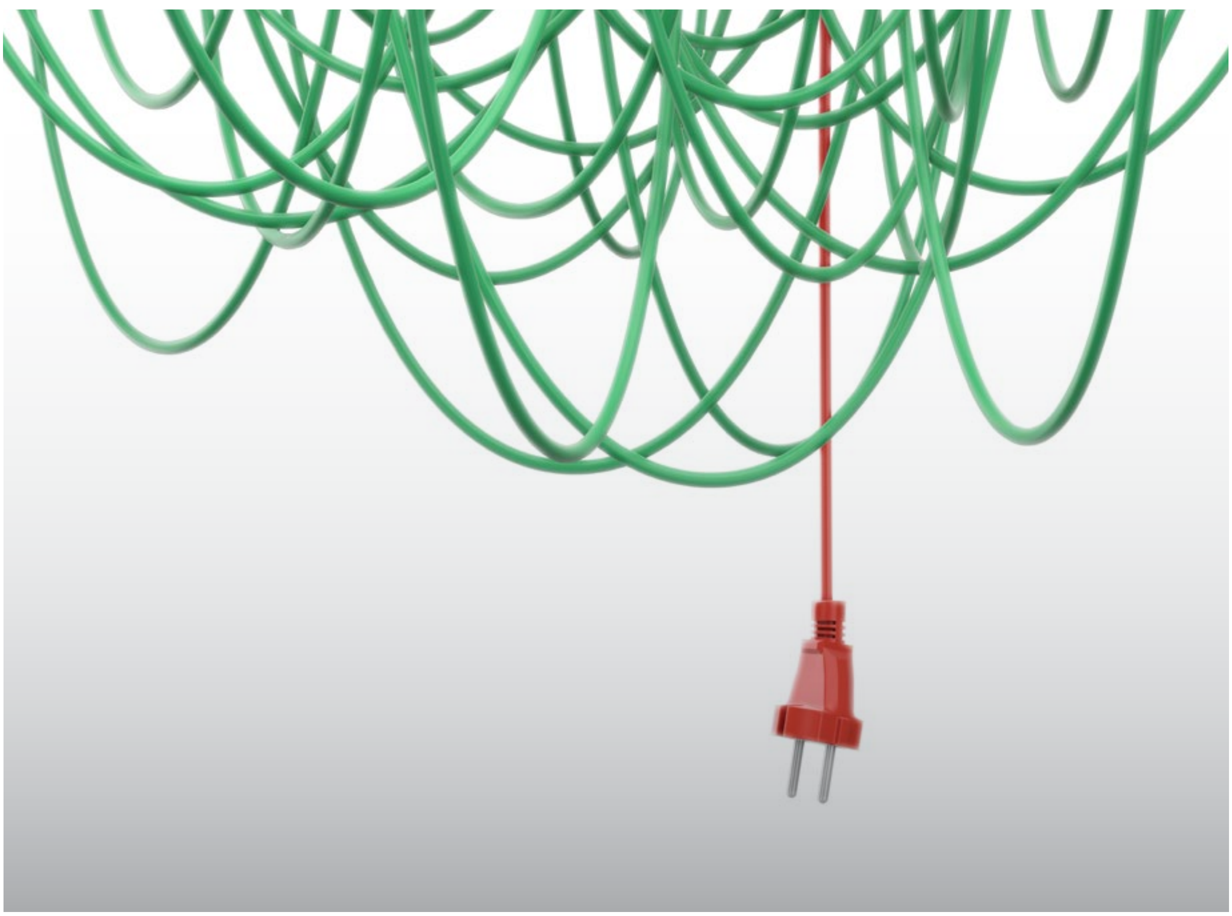
Plant Services

Quantity vs. quality: Understanding the causes of poor power quality



Find Industrial Energy Waste

Identify problems, quantify solutions, and prove the ROI

By Leah Friberg, Fluke

☐ With energy savings, there's intent and then there's plan. Industrial facilities in the United States show a sustained interest in energy management. That's the intent: Reduce overall energy usage or sustain usage but increase the amount produced per kW used. The plan? Sometimes that's a problem.

In manufacturing, a plan will only stick if it has both the wisdom of experience guiding the vision and the ROI numbers to back up the reason. But in energy, there just isn't the body of research out there for an industrial plant manager to use, to set baselines for what "reasonable" energy usage looks like in a manufacturing facility. So, how do you assess what portion of current energy usage is reasonable and what is wasteful, or of that wasteful portion, what provides high enough ROI to address?

The ROI under discussion here is the cost/kWh as charged by the utility. Those units carry a different rate depending on time of day and year. Reducing that expense is the savings. The investment is the materials and labor required to change energy consumption. The return is the period of time it takes for the reduced utility bill to pay for the investment. The gravy comes after the expense is paid off.

Returning to the issue of the plan, how then do you draw up an ROI estimate when there is no industry standard for reasonable energy usage?

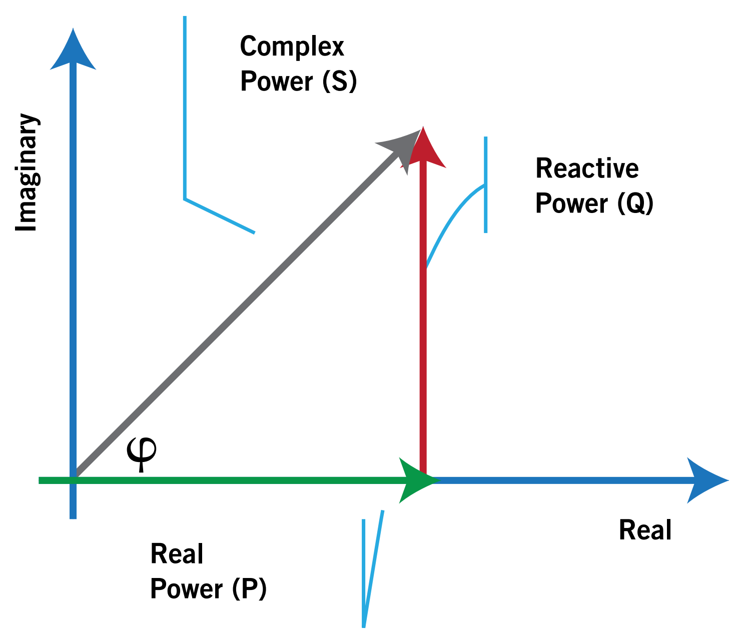
PROFILING INDUSTRIAL ENERGY USAGE

Industrial energy usage varies based on mulitple variables:

- plant age
- load type and size
- operational schedule, both hours/week and intensity of loading
- number of workers
- climate
- maintenance philosophy.

The answer is: Don't try to manage every kW consumed by your facility. This is the "wisdom of experience" part of the equation. Divide the facility into the electrical infrastructure and then key systems.

Energy savings start with two basic tactics: a general inspection of key



ENERGY DEFINITION AND MEASUREMENT

Figure 1. Energy is expressed in real, reactive, and apparent power.

systems and targeted data gathering, including logging energy usage at the main service entrances and at those key loads. Identify how much a system is specified to consume, determine how much it is currently consuming, and identify wasteful practices, either in the hours and type of operation, or in the equipment/system itself. To achieve the savings, the facility must address the waste, either by changes in operation, in maintenance, or in equipment/controls.

ENERGY COMPONENTS

Before we explain how to trace energy consumption, let's revisit how we define and measure energy.

Energy is expressed in real, reactive, and apparent power (Figure 1).

Energy flow is described by:

- real (P) or active power in Watts (W)
- reactive power (Q) in Volt Ampere reactive (VAR)
- complex power (S) in Volt Ampere (VA)
- apparent power, the magnitude of complex power (VA).

The mathematical relationship of real, reactive, and apparent power can be represented by vectors or expressed using complex numbers, $S = P + jQ$ (where j is the imaginary unit).

Reactive power does not transfer energy — it does not produce work — so it is represented as the imaginary axis of the vector diagram. Real power moves energy, so it is the real axis.

The rate of energy flow in a system is dependent on the load — is it resistive, reactive, or both?

With a purely resistive load, voltage and current reverse polarity at the same time, at every instant the product of voltage and current is positive, and only real power is transferred. Therefore, work is produced.

If the load is purely reactive, the voltage and current are out of phase, and the product of voltage and current can be positive or negative, indicating some portion of the energy is transferred to the load and some portion flows back. The net transfer of energy to the load is zero: no work is produced.

In reality, all loads have a combination of resistance, inductance, and capacitance, creating both real and reactive power in a system. For that reason, electrical systems are designed to tolerate a certain amount of reactive power. The problem comes when too much reactive power is generated. Not only is there insufficient real power to produce the required work, but the overall work-generation capacity of the system is compromised. That's why utilities penalize their customers if their loads produce too much reactive power: It's waste power that costs money to generate, but can't be used. Most utility bills track VARs (reactive power), and many calculate power factor, where power factor is a rating of how far below 100% real power a system has fallen. Most utilities require their customers to stay above .95 PF.

TRACING ENERGY CONSUMPTION

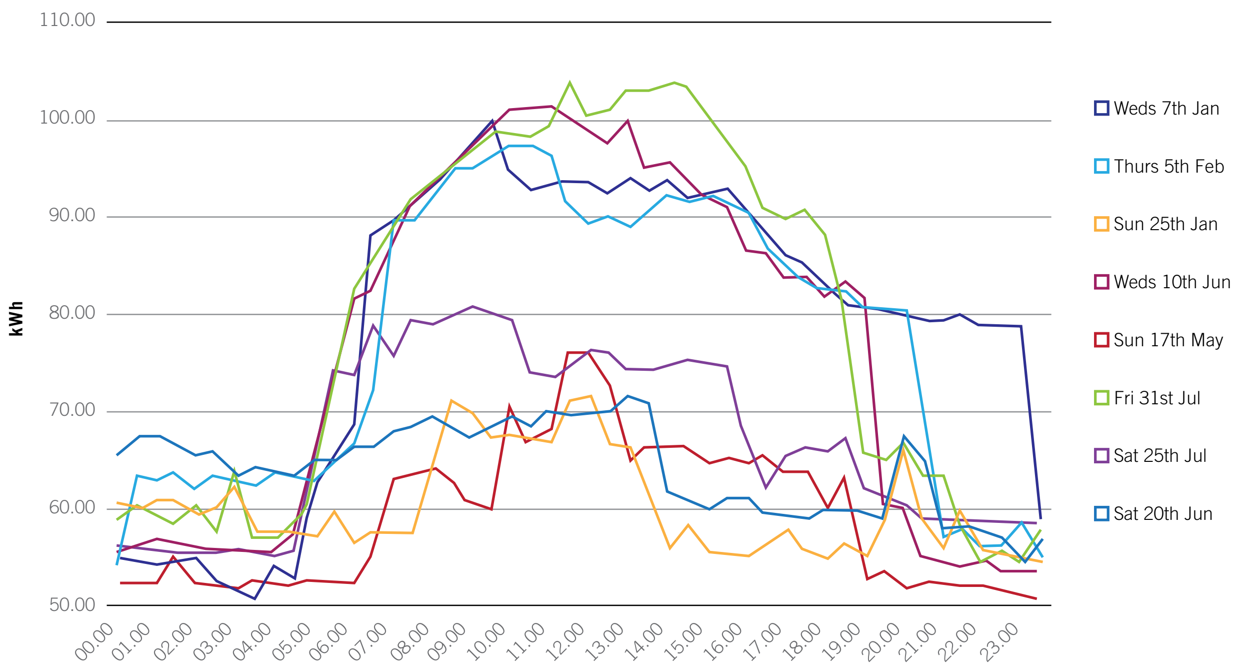
The understanding of basic energy components enables an electrician to set up energy logging equipment to measure overall level and quality of consumption and then trace when energy is consumed by what (Figure 2).

Log power at the main and secondary panels and at major loads. Record kW, kWh, and power factor over a representative period of time.

This provides a very accurate picture of the real power consumption on three-phase circuits and loads.

The biggest power savings come from determining when power usage peaks, evaluating power factor and overall power consumption compared to utility invoices, and possibly rebalancing loads. Even just a couple minutes of peak usage can increase the utility rate for a couple hours, days, or weeks.

Rescheduling loads may allow a company to take advantage of times of day when power is cheaper. Check how far below "1" the power factor is, and check the utility invoices to see if there's a penalty for poor power factor.



ENERGY CONSUMPTION

Figure 2. Set up energy logging equipment to measure overall level and quality of consumption and then trace when energy is consumed.

If there is, the power logger can help to trace the sources. Then, after you've made energy upgrades, reconnect the logger to prove out the benefit of your efficiency improvements.

UNDERSTANDING ENERGY WASTE POINTS

Every system and operation has the potential to be a point of waste that can be mitigated or remedied. Electrical subsystems, compressed air, steam, and specific electromechanical systems are a good place to start, but each operation has its own potential waste points that should be measured.

The goal is to map the energy use of specific equipment and processes to look at where energy is being wasted to quantify the waste and prioritize improvements or replacements, based on life of the equipment and which modifications can deliver the best return on investment.

Energy mapping also provides a baseline from which to measure the effectiveness of energy saving projects to justify the cost.

Common wastes in the electrical subsystems:

- Loads commonly left on after hours or unnecessarily run at peak rate time of day.
- No controls on motor might mean more output created than required.
- Over-voltage/current conditions cause excessive power consumption to compensate.
- Phase unbalance causes the load to consume power without being able to use it.

Identify and quantify:

- Thermal scan the electrical panel and mechanical load for overheating.
- Log power over time: How much power is consumed at what time of day and with what amount of waste?

Common wastes and inspection points in electromechanical systems:

- Excess friction from alignment, bearings, imbalance, and looseness overworks the motor, consuming excessive power.
- Uncontrolled loads left on after hours, run at peak rate times, create more output than required, or suffer from over-voltage/current conditions and phase unbalance.

TEST THEM ALL
Figure 3. How do we really know which systems hold the most potential energy ROI?

- Aging mechanical devices consume so much more power than new high-efficiency models that early replacement may be justified in reduced kWh consumption alone.

Identify and quantify:

- Thermal scan the drive panel and mechanical load for overheating indicative of electrical inefficiency.
- Log power over time; check total kWh, power factor, peak demand, unbalance, and harmonics.
- Test vibration levels against standards and identify maintenance solutions such as rebalancing.
- Thermally scan couplings/shaft/belts, bearings, and fan.
- Check current and voltage levels.
- Thermally scan termination/junction box and windings, and conduct insulation resistance testing.

Common wastes and inspection points in compressed air systems:

- Excessive leaks in compressed air lines lead to excess operation to maintain supply.
- Compressors left on outside of time of usage waste energy.

Identify and quantify:

- Power log at compressor to baseline consumption.
- Measure pressure at compressor and point of use to determine amount of drop.
- Ultrasound scan lines to identify leaks.

Common wastes and inspection points in steam systems:

- Failed steam traps and insufficient insulation waste steam, causing over-production to maintain necessary supply.

Identify and quantify:

- Power log at boiler to baseline consumption.
- Thermally scan pipes and traps to identify insulation gaps and blockages.

Prove the ROI

With the aforementioned lack of industry standards, how do we really know which systems hold the most potential energy ROI (Figure 3)? Our best material right now is case examples that embody common situations. Here are several examples for common industrial systems.

ELECTRO-MECHANICAL INSPECTION

Facility type: steel recycling plant in Germany

Equipment type: belt-driven fan, for process cooling

Measurements taken: vibration testing

Problems noted: moderate unbalance, along with misalignment and bearing wear

Savings: Rebalancing was required. A 350 kW motor was running at 80% of nominal power; measured power was about 280 kW. After rebalancing, power consumption was reduced by 3%. At a cost of 0.11 euro/kWh, annual savings tallied 8,094 euros.

COMPRESSED AIR INSPECTION

Facility type: manufacturing

Equipment type: compressed air system

Measurements taken: ultrasound inspection of compressed air system (recommended complete data logging of compressor)

Problems noted: amount of compressed air produced in comparison to the actual demand

Savings: Multiple savings opportunities were found. Total annual savings of $50,600. Shutting down compressor on weekends: annual savings of $32,700. Install solenoids, to shut air off when machines are shut off: annual savings of $7,100. Repair 36 leaks: annual savings of $4,800. Filters installed in the system at a one-time cost of $6,000; annual savings as a result of the filters: $6,000.

COST SAVINGS TIPS

Change operations to take advantage of:

- lower cost energy times of day
- times when machinery can be turned off
- sensors and controls that could enable systems to be turned off when not needed.

Set up infrastructure equipment startup/shutdown schedules for occupied vs. unoccupied modes.

For startup, stage equipment with large electrical power consumption at least 15 minutes apart to avoid peak demand charges.

Install variable-frequency drives (VFDs) for large motors and replace existing bad motors with high-efficiency models.

STEAM TRAP INSPECTION

Facility type: manufacturing

Equipment type: boilers and steam lines

Measurements taken: thermal inspection of steam line

Problems noted: six steam traps not operating properly; leaking coils in the plating tanks; steam leaks at plating lines; opportunities to recover condensate

Savings: Six failed traps were replaced at a cost of $500 per trap. Savings achieved: $3,200 per trap using known cost to generate steam and heat loss calculations. Total savings: $16,200.

Next step: Energy log at boiler supply panel before and after addressing leaks and condensate issues.

INCREASED PRODUCTIVITY OR REDUCED OVERHEAD?

The next question is a an important one: Once you identify a path to reduced energy consumption, do you funnel that savings into increasing the plant yield (same kWh consumption producing greater volumes) or into other business strategies (profit margins, price realization)?

Reducing energy consumption is just good business. By power logging each major system and mapping those costs against utility bills to quantify where and when consumption is occurring, companies can often realize savings by simple operational and schedule changes. By identifying inefficient or outdated equipment, companies can justify and prioritize replacement. And, by reducing overall energy consumption, companies reduce operating costs, improving their competitiveness in the marketplace. ◻

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Quantity vs. quality: Understanding the causes of poor power quality

You might be a victim of power quality problems and not even know it

Many companies monitor the cost of energy, but the smarter companies also pay attention to the quality of their power. By measuring and examining historical energy usage throughout the facility, you can start to get a rhythm or a heartbeat for your plant and understand where you can make improvements to your energy usage.

In a recent Plant Services webinar, Han Tran, application engineer for Fluke, explored why measuring power and understanding the quality of your power is the key to helping plants avoid unplanned outages.

CRITICAL MEASUREMENTS: QUANTITY VS. QUALITY

The first step to improving energy usage is understanding the difference between quantity and quality. Quantity often has units associated with it like volts, amps, kilowatts, kVAs, and kVARs. Typical actions associated with quantified data include performing load studies to determine if it's possible to add a machine to your facility or trending your energy usage to get an understanding of the rhythm of your plant. By exploring how and why your facility is using energy at certain times of the day, you will also gain control of your energy bill.

Quality, on the other hand, isn't usually associated with units, but it is associated with characteristics like harmonics, dips and swells, transients, and more. Typical actions associated with measuring power quality are detecting reoccurring issues, like nuisance tripping breakers, or performing in-depth analyses to find intermittent disturbances. Taking these actions will help reduce utility penalties (or avoid them completely) and help prolong the life of your equipment.

QUANTITY: POWER

Power, which is measured in kilowatts, is the rate at which AC energy is expended. It is also called actual power, active power, or real power. It is the measure of the energy required to do actual work, such as running a motor. If you're not properly monitoring or tracking power at your facility, then you run the risk of having a surcharge on your next utility bill, and no one wants that. Another benefit of tracking volts, amps, and watts over an extended period of time is the identification of potential waste and savings opportunities.

QUANTITY: DEMAND

Demand, which is measured in kilovolt amps, is the total voltage and current required from the utility regardless of the efficiency or whether it's actually producing work for your facility. When you look at your utility bill, you will see the maximum demand charge and the fixed demand charge. A surcharge occurs when you go beyond the demand. Unfortunately, it doesn't matter how long you went over your peak demand rate; you will be charged for the entire billing period.

QUANTITY: POWER FACTOR

Power factor is a description of the efficiency of operation of an electrical system. If your power factor is one, then your system is 100% efficient, at least from the utility's point of view. If your power factor is less than one, then there are losses in the system. These losses force the utility to turn on additional generators, the same as if you went over your peak demand, and the utility passes these additional costs on to the consumer.

In some areas, the utility will want the consumers of power to have a power factor of .95 or above. If you go below .95, you will get a surcharge because you're injecting poor power quality back onto the grid that the utility has to compensate for, and so they pass the charge back on to you. To correct power factor issues, you can either hire a third-party provider or you can purchase a power quality tool that will tell you what your circuit looks like and then have an electrical engineer design a circuit that can correct for that power factor and adjust for it.

QUALITY: DIPS AND SWELLS

Dips and swells are a qualitative power issue. If you have a line voltage that is higher than your nominal voltage, then you have a swell. If you have a line voltage that is lower than your nominal voltage, then you have a dip. You can have intermittent loss of power if you have a dip or a swell, and you can even damage your equipment depending on its sensitivity. Certain power quality tools can count the number of dips and swells that occur in a system, and some can actually provide the date and time when the incident occurred. If you know your facility well enough, you can go back and correlate the incident to a specific piece of machinery that might have been firing on at that particular time.

QUALITY: TRANSIENTS

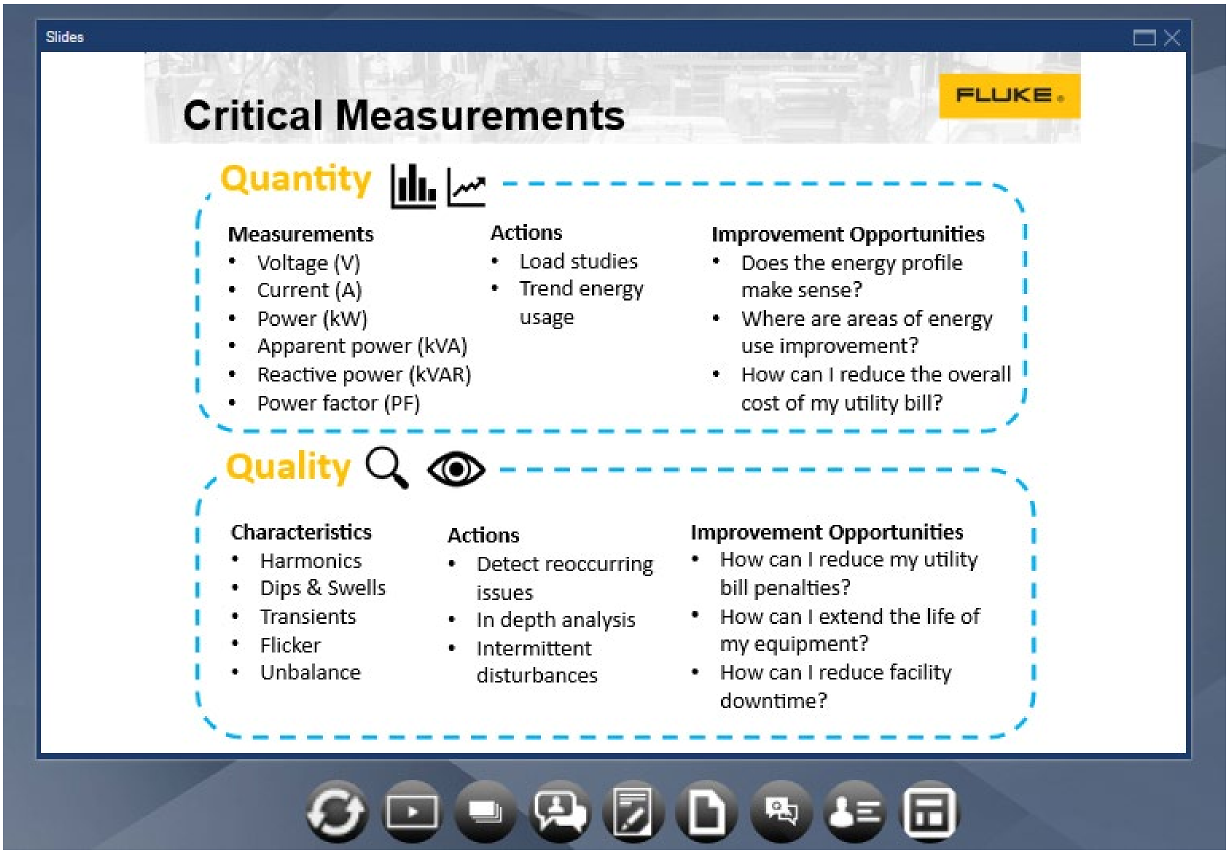
Transients are events that happen during less than one-half cycle on the AC line. Transients are interesting because there are different types of transients, and when you are trying to engineer a solution for a transient issue, you want to pick the right circuitry. There are two types of transients: fast-acting and oscillatory.

Fast transients include things like lightning strikes. They are large voltage changes that happen in a very small timeframe. Some people might call them surges or a spike, but the proper term would be transients. Oscillatory transients occur when you have little arcs happening or when you have switch gears that have faulty contacts. This can happen when you have poor-quality contacts or if they're not rated for a particular application.

QUALITY: UNBALANCE

Unbalance is another qualitative power issue. Generally, the three stages of voltage should always have similar magnitude. Voltage and current unbalance occurs when three-phase voltages differ in magnitude, when three-phase currents differ in magnitude, or if they don't have 120 degrees phase displacement. Traditionally, customers would use an O-scope and a DMM to calculate the percentage of unbalance, but this method can be challenging because power is very dynamic and can change. With a three-phase power quality analyzer, you can hook up your current transducers with your voltage alligator clips and it will take the measurements in one shot.

Properly diagnosing a voltage or current unbalance has immediate benefits. Because voltage unbalance can cause current unbalance, diagnosing the voltage unbalance can help you avoid things like motors that trip because of current overload salt protection devices. □



To learn more about power quality, watch the on-demand webinar.

https://info.plantservices.com/webinar-2018-power-quality-issues_es