Harmonics and utility costs

Understand harmonic effects to avoid utility violations and equipment damage.

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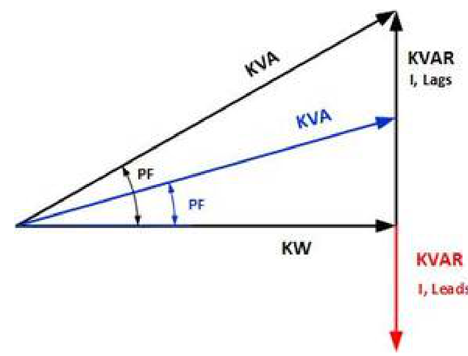
Harmonics is a result of an electrical device's nonlinear behavior; know how to make power-related measurements to avoid utility contract violations and penalties for large commercial and industrial facilities. Use the power triangle to understand interactions of real power, apparent power, reactive power, and power factor.



The power triangle

The "power triangle" in Figure 1 illustrates the relationship between the quantities of real power (kW), apparent power (kVA), reactive power (kVAR), and power factor (PF) found in ac sinusoidal power distribution systems:

- **kW:** Real power is the rate at which electrical energy is converted to work, measured in kW. This vector quantity is defined in the power triangle on the horizontal axis at 0-deg as kVA*PF: Where PF is the cosine of the displacement angle between current and voltage with no harmonics.
- **kVA:** The magnitude of the product of voltage across a load multiplied by the current through the load has the units of watts and is the vector kVA with the PF angle in Figure 1.
- **kVAR:** The kVAR quantities have a +/- rotation and are the product of voltage across the net reactance (inductance, capacitance, or a combination) multiplied by the current flowing through this reactance element. This represents the units of reactive watts.
- **PF:** The system power factor is the cosine of the angle whose tangent is the net kVAR divided by kW. The power factor angles represent the "displacement" angle between voltage and current caused by the system reactive elements of inductance and capacitance.

Utility billing for facilities

Utility companies sell electrical energy in the units of kilowatt-hours, kWh. Residential customers pay what appears to be a flat rate per kWh; large commercial and industrial facilities usually enter into a contract which often has penalties for contract violations. The rate of energy utilization per time is kilowatt units (kW), which utilities define as "demand" with kW. Large customers are required by some utilities to maintain the power factor (kW ÷ kVA) within a contract range.

In the accepted topology for a consumer's facility, the user's load is modeled as the typical parallel combination of resistance, inductance, and an optional capacitance. Figure 2 illustrates power triangle conclusions regarding the behavior of single frequency ac loads without harmonics when a capacitor is added.

Without capacitance reactance, XC

kVA	Iline, RMS	PF < °	PF	kW
27.72	133.19	14.47°	0.96828	26.82

With added capacitance reactance, XC

kVA	Iline, RMS	PF < °	PF	kW
26.95	129.56	5.53°	0.9954	26.82

Effects of harmonics in sinusoidal power distribution systems

A variety of situations can create harmonics in a facility:

- Modern electrical equipment with embedded microprocessors and electronic circuitry generally represents a nonlinear load that results in harmonics-rich, nonsinusoidal line currents
- Modern LED lighting
- Nonlinear magnetic fields in transformers and rotating air gaps
- Transformer core, eddy current, and winding skin effect losses increase with frequency
- Transformer operating performance is distorted by dc current components, which create additional nonsinusoidal currents
- Other high frequency losses occur throughout the plant.

Harmonics create nonsinusoidal line currents in the form of pulses which is a by-product of nonlinear loads. Their presence means that current and voltage are distorted, adding strain to electrical systems that can lead to equipment damage, power supply failures, and plant downtime.

Harmonics are reflected onto the utility grid and accumulate as customers add more modern electronics. In addition to ongoing maintenance costs, harmonics can result in financial penalties for lack of compliance with a utility's harmonic limits. To avoid these situations, it is important to answer crucial questions, including:

- Are there harmonics in my system?
- Is there a penalty for harmonics?
- What quantities will be charged?
- How does the utility company measure billing items and account for additional losses?
- Will the utility company provide an onsite analysis and negotiate billing?

By answering these questions, the appropriate measures can be taken to mitigate harmonic effects.

For additional details and equations regarding harmonics and utility costs, download Application Note 129.

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MORE ADVICE

Key Concepts

- **The costs associated** with harmonics and sinusoidal power distribution systems
- **Situations** that can create harmonics at a facility
- **Compliance** with a utility's harmonic limits.

Consider this

As organizations update facilities to incorporate advanced technology and electronics, are existing electrical systems at risk of being strained or damaged?

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