How to recognize harmonics symptoms – What to look for and where to look?

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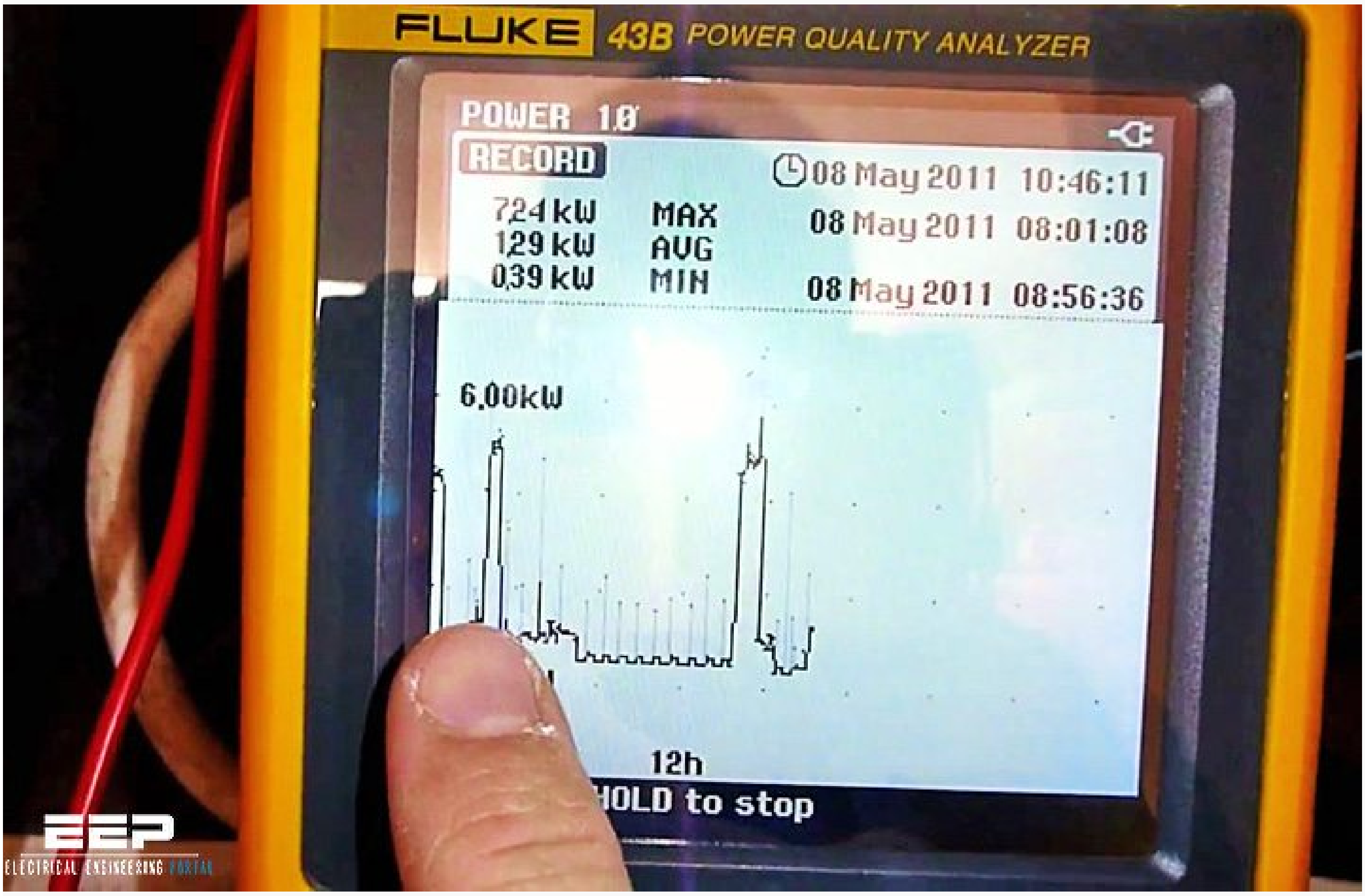
Harmonics symptoms

Finding harmonics problem is relatively easy once you know **what to look for and where to look**. Harmonics symptoms are usually anything but subtle. This technical article provides some basic pointers on how to recognize problems with harmonics in power distribution equipment.

Symptoms of harmonics usually show up in the power distribution equipment that supports the non-linear loads. There are two basic types of non-linear loads: **single-phase and three-phase**. Single-phase, non-linear loads are prevalent in offices, while three-phase loads are widespread in industrial plants.



How to recognize harmonics symptoms - What to look for and where to look? (on photo: Fluke 43B Single Phase Power Quality Analyzer; credit: mjlorton via Youtube)

Each component of the power distribution system manifests the effects of harmonics a little differently, yet all are subject to damage and inefficient performance if not designed to handle electronic loads.

Contents

Power distribution equipment:

1. Neutral conductors

In a three-phase, four-wire system, neutral conductors can be severely affected by non-linear loads connected to the 120 V branch circuits. Under normal conditions for a balanced linear load, the fundamental 60 Hz portion of the phase currents will cancel in the neutral conductor.

In a four-wire system with single-phase, non-linear loads, certain odd-numbered harmonics called **triplens – odd multiples of the third harmonic: 3rd, 9th, 15th, etc.** – do not cancel, but rather add together in the neutral conductor.

In systems with many single-phase, non-linear loads, the neutral current can actually exceed the phase current. The danger here is **excessive overheating** because, unlike phase conductors, there are no circuit breakers in the neutral conductor to limit the current.

Excessive current in the neutral conductor can also cause **higher-than-normal voltage drops** between the neutral conductor and ground at the 120 V outlet.

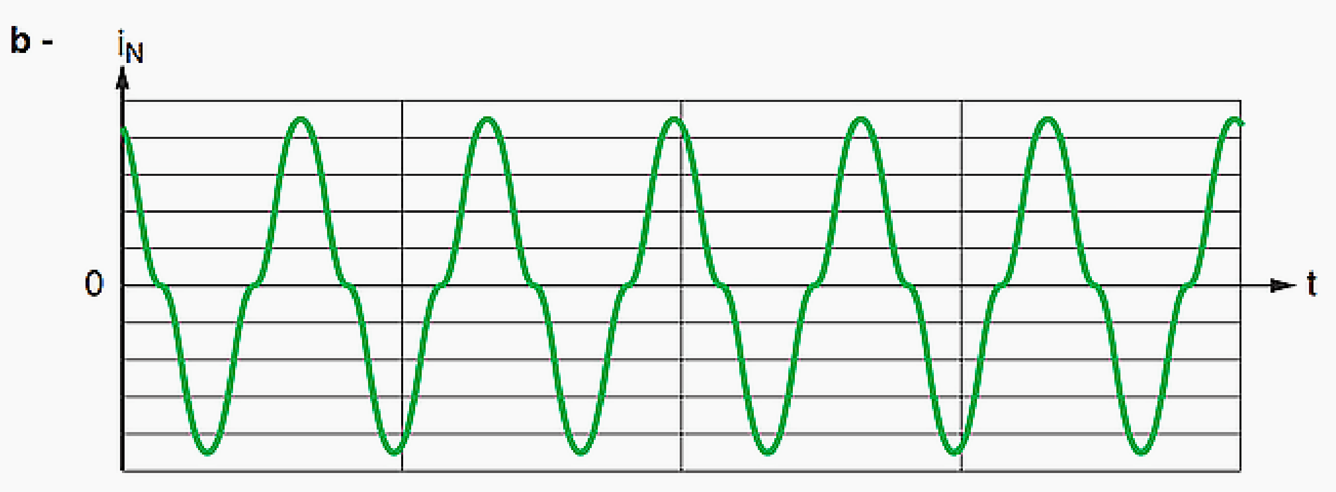


Figure 1 – Neutral current distorted by harmonics

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2. Circuit breakers

Common thermal-magnetic circuit breakers use a bi-metallic trip mechanism that responds to the heating effect of the circuit current. They are designed **to respond to the true-rms value of the current waveform and will trip when the trip mechanism gets too hot**.

This type of breaker has a good chance of protecting against harmonic current overloads.

A peak-sensing, electronic trip circuit breaker responds to the peak of current waveform. As a result, it won't always respond properly to harmonic currents. Since the peak of the harmonic current is usually higher than normal, this type of circuit breaker may trip prematurely at a low current.

If the peak is lower than normal, **the breaker may fail to trip when it should**.

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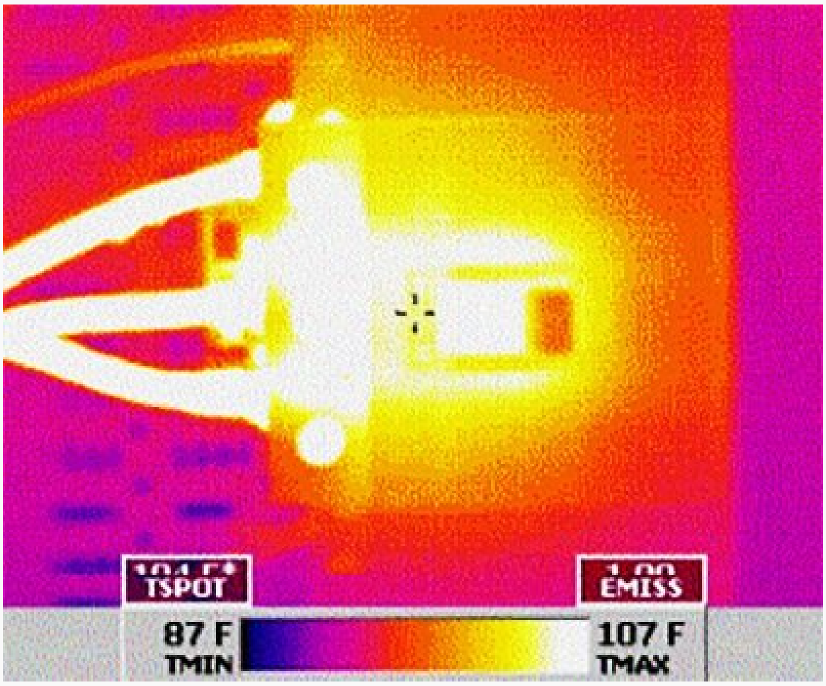

Thermal image that shows overheated conductors and contacts on line side of circuit breaker (photo credit: irinfo.org)

3. Bus bars and connecting lugs

Neutral bus bars and connecting lugs are sized to carry the full value of the rated phase current. They can become overloaded when the neutral conductors are overloaded **with the additional sum of the triplen harmonics**.

4. Electrical panels

Panels that are designed to carry 60 Hz currents can become mechanically resonant to the magnetic fields generated by higher frequency harmonic currents. When this happens, **the panel vibrates and emits a buzzing sound at the harmonic frequencies**.

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5. Transformers

Commercial buildings commonly have a 208/120 V transformer in a delta-wye configuration. These transformers commonly feed receptacles in a commercial building. Single-phase, non-linear loads connected to the receptacles produce triplen harmonics, which add up in the neutral.

When this neutral current reaches the transformer, **it is reflected into the delta primary winding where it causes overheating and transformer failures**.

Another transformer problem results from core loss and copper loss. Transformers are normally rated for a 60 Hz phase current load only. Higher frequency harmonic currents cause increased core loss due to eddy currents and hysteresis, resulting in more heating than would occur at the same 60 Hz current.

These heating effects demand that transformers be derated for harmonic loads or replaced with **specially designed transformers**.

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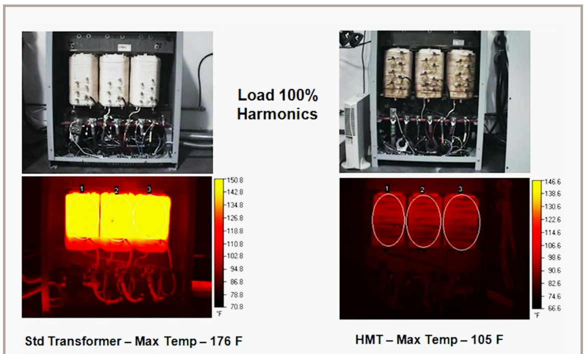


Overheated transformer due to harmonics

6. Generators

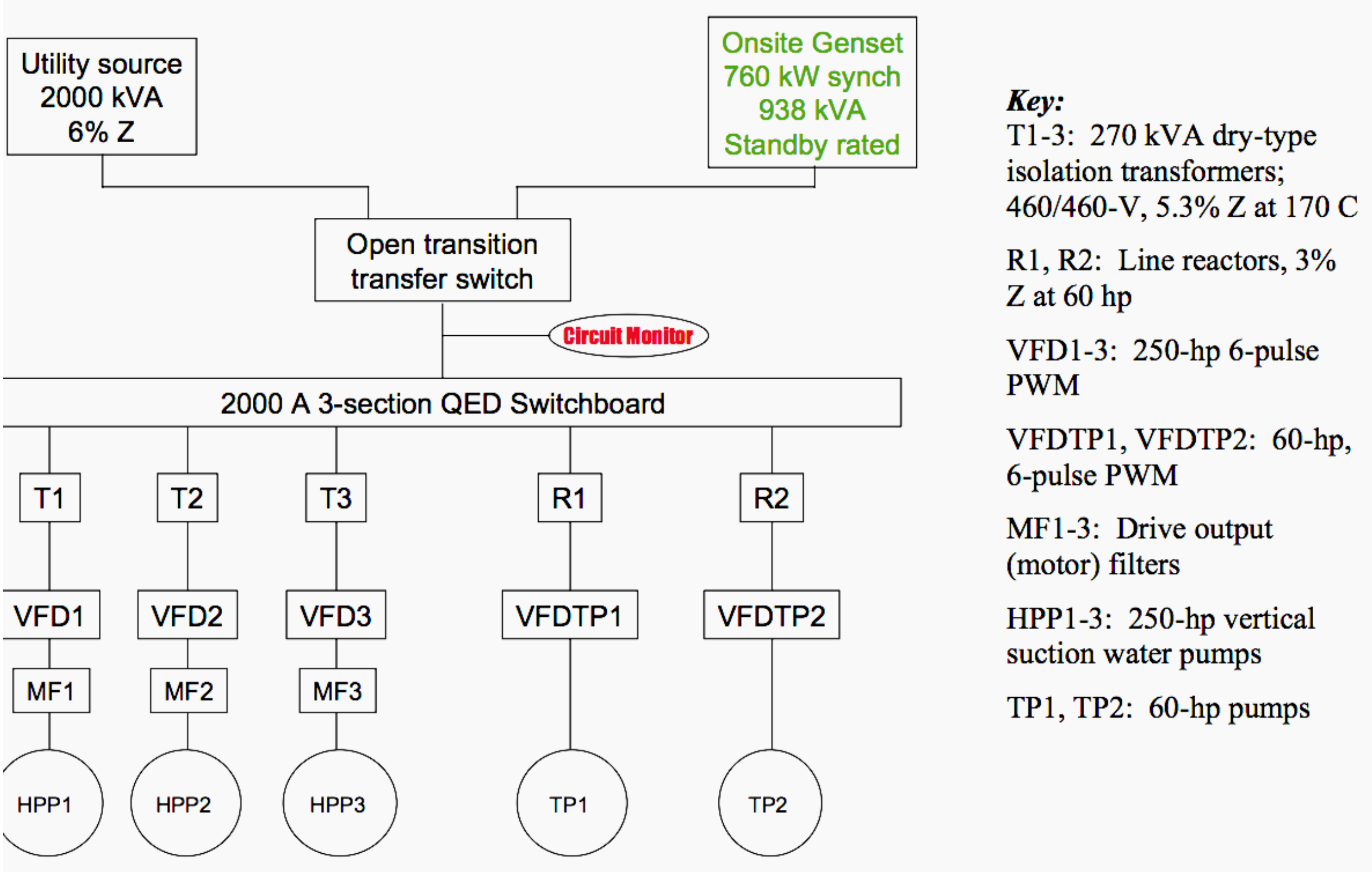
Standby generators are subject to the same kind of overheating problems as transformers. Because they provide emergency backup for harmonic producing loads such as data processing equipment, they are often even more vulnerable.

In addition to overheating, certain types of harmonics produce distortion at the zero crossing of the current waveform, **which causes interference and instability for the generator's control circuits**.

Example from Square D Engineering Services

Water treatment plants are often equipped with variable-frequency drives, ozone generators, and other loads that produce harmonic distortion. These facilities are also equipped, in many cases, with emergency standby generators required to operate critical electrical loads during extended electric utility outages. One such facility, a reverse osmosis desalination plant located on the United States coast, was concerned about the **ability of its 938-kVA standby generator to operate reliably in the presence of harmonic distortion** injected by large VFD's serving pump motors.

Subsequent harmonic measurements compared distortion levels on both utility and generator sources, and engineering analysis offered **harmonic mitigating techniques indicated by the measured harmonic levels**.



Generator Loading, Harmonics Monitoring and Mitigating Analysis in a Water Treatment Plant

Since there is no space for explaining the whole study of Square D, let's give summary of what they did in order to achieve harmonics reduction:

Bypassing one of the existing three isolation transformers serving a 250-hp drive seems to have a beneficial effect on the amount of harmonic current distortion at the facility. As shown in the following summary, cancellation effects can be improved to further reduce 5th and 7th harmonic currents by bypassing one transformer and allowing its 5th and 7th harmonic currents to be unchanged. Once these currents are added to the other one or two 250-hp drive currents, additional cancellation occurs.

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7. Telecommunications

Telecommunications systems often give you the first clue to a harmonics problem because the cable can be run right next to power cables. To minimize the inductive interference from phase currents, telecommunications cables are run closer to the neutral wire.

> *Triplens in the neutral conductor commonly cause inductive interference,* ***which can be heard on a phone line****. This is often the first indication of a harmonics problem and gives you a head start in detecting the problem before it causes major damage.*

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Solutions to compensate for and reduce harmonics

While standards to limit the generation of harmonic currents are under consideration, harmonic control today relies primarily on remedial techniques. There are several approaches that can be taken **to compensate for or reduce harmonics in the power system**, with varying degrees of effectiveness and efficiency.

1. Oversize the neutral wiring

In modern facilities, the neutral wiring should always be specified to be the same capacity as the power wiring, or larger—even though electrical codes may permit under-sizing the neutral wire. An appropriate design to support a load of many personal computers, such as a call center, would specify **the neutral wiring to exceed the phase wire capacity by about 200 percent**.

> ***Particular attention should be paid to wiring in office cubicles!*** *Note that this approach protects the building wiring, but it does not help protect the transformers.*

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2. Use separate neutral conductors

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.

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3. Use DC power supplies, which are not affected by harmonics

In the typical data center, the power distribution system converts 480-volt AC utility power through a transformer that steps it down to 208-volt AC power that feeds racks of servers. One or more power supplies within each server convert this AC input into DC voltage appropriate for the unit's internal components.

These internal power supplies are not energy efficient, and they generate substantial heat, which puts a costly burden on the room's air conditioning system. Heat dissipation also limits the number of servers that can be housed in a data center.

Could it be worthwhile to eliminate this step by switching to DC power?

According to article in Energy and Power Management magazine, Computers and servers equipped with DC power supplies instead of AC power supplies **produce 20 to 40 percent less heat, reduce power consumption by up to 30 percent**, increase server reliability, offer flexibility to installations, and experience decreased maintenance requirements."

That sounds good, but when cost, compatibility, reliability and efficiency are considered together, the move from AC to DC power is not justified for most data centers. AC power – even though it is slightly less efficient – is universally acceptable to existing equipment.

> *Furthermore, there are no Underwriter's Laboratory (UL) safety standards for high-voltage DC in data centers yet, while standards for AC systems are mature.* ***That means the safety risks could outweigh the potential gain with DC power, for now.***

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4. Use K-rated transformers in power distribution components

A standard transformer is not designed for high harmonic currents produced by non-linear loads. It will overheat and fail prematurely when connected to these loads. When harmonics were introduced into electrical systems at levels that showed detrimental effects (circa 1980), the industry responded by developing the K-rated transformer.

> ***K-rated transformers are not used to handle harmonics****, but they can handle the heat generated by harmonic currents and are very efficient when used under their K-factor value.*

K-factor ratings range between 1 and 50. A standard transformer designed for linear loads is said to have a K-factor of 1. The higher the K-factor, the more heat from harmonic currents the transformer is able to handle. Making the right selection of K-factor is very important, because it affects cost and safety.

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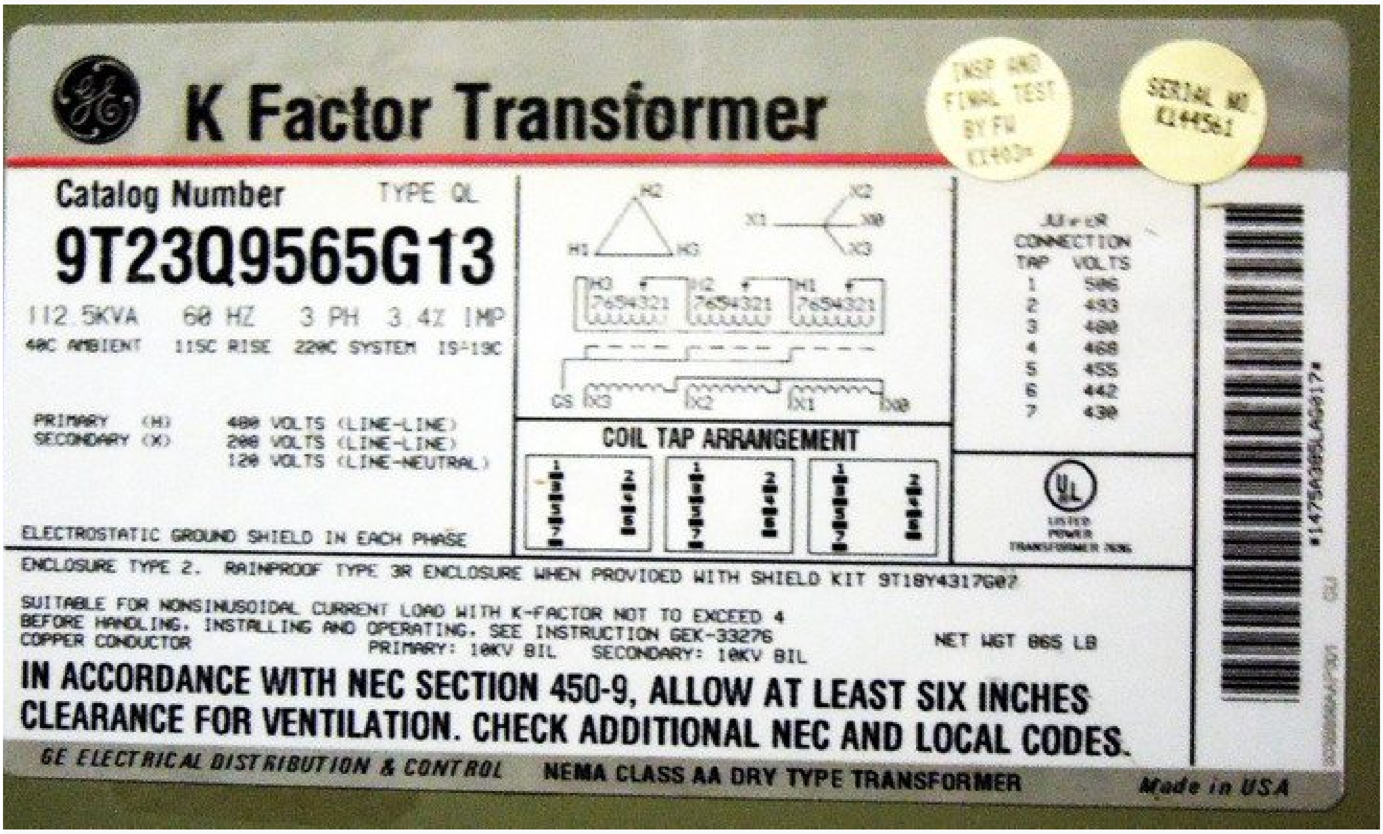
Dangers and Damage from Electrical Harmonics

Learn about harmonics in your electrical system. It’s not if, but how much. Harmonics produce **dangerous**



K-rated transformer nameplate (photo credit: emscomn.com)

problems which include fire and equipment failure from constant overheating.

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2. *Harmonics in your electrical system by EATON*
3. *Generator Loading, Harmonics Monitoring and Mitigating Analysis in a Water Treatment Plant by Eddie Jones, PE; Larry Ray, PE; Tim Shuter, PE; Square D Engineering Services*