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Quality Matters

Awareness of the Basic Issues of Power Quality and How To Tackle Them

feature ARTICLE **AEMC® INSTRUMENTS**

Quality Matters

Awareness of the Basic Issues of Power Quality and How To Tackle Them

BY JOHN OLOBRI

IF YOU OWN OR RUN A BUSINESS, it's very likely that one of the things you're least likely to think about on a regular basis is the quality of your electricity. For a start, what is power quality and how can it vary? Surely you can depend upon your energy supplier to look after this sort of thing, and anyway, does power quality really matter or is it just something for specialist engineers to worry about? In this article we're going to answer those questions, but let's start off by saying that power quality is most definitely a concern for us all.

Have you ever had a piece of equipment – most likely a computer or other electronic item – that functioned poorly or failed regularly for no apparent reason?

Maybe you have lights that flicker, or if you operate a factory, motors that run hot and fail sooner than expected. All of these could be the results of poor power quality and if you don't realize this, the time and money you spend on trying to fix the symptoms is likely wasted. Power quality issues can also increase your energy bills, eating further into your hard-earned profits.

For these reasons, everyone who owns or runs a business needs to be aware of the basics of power quality, to understand how to assess it, and to know what to do if and when problems are identified. A few minutes spent reading this article could save you a lot of time, trouble and money.

What is Power Quality?

In a perfect world, you would expect your electricity supplier to provide you with an AC supply at a constant voltage, a fixed frequency, and with perfectly sinusoidal waveforms that have no nasty spikes on them. Also, if it is a three-phase supply, you would expect the voltages of the three phases to be exactly the same. This would be perfect power quality. However, as we don't live in a perfect world, your supply may not actually meet these requirements and even if it does meet them at the point it enters your premises, it may well become degraded as it passes through the electrical installations at your site.

As this suggests, if you have power quality issues, in many cases it's not the fault of your utility company. The operators do, in fact, go to great lengths to ensure that they deliver clean supplies, but some of the factors that affect supply quality, such as thunderstorms and the equipment you've got installed in your own premises, are beyond their control.

That said, what can possibly go wrong with power quality? In practice, almost all power quality issues can be divided into six main areas. These are: harmonics, sags and surges, transients (spikes), interference, voltage imbalance and poor power factor. Let's examine each of these issues.

Harmonics

In an ideal power system, voltage and current waveforms would be perfectly sinusoidal. This would not be too difficult to achieve if all the loads connected to the power system were linear – that is, the loads where the current drawn from the supply is always proportional to the applied voltage. Basic heaters and incandescent lighting are examples of linear loads and, until the last few decades of the 20th century, loads were predominantly of this type.

Within the last 30 years, however, there has been a big increase in the number of non-linear loads connected to the electrical network. These include computers, uninterruptable power supplies, variable speed motor drives, electronic lighting ballasts and LED lighting, to name a few. The growing use of such equipment, and the use of electronics to control nearly all types of electrical loads, have an effect on the electricity supply and on individual site installations. It is estimated that today over 95% of the harmonics present on a given site are generated by equipment installed at that site.

As we have stated, when a linear load is connected to the supply it draws a sinusoidal current at the same frequency as the voltage. Non-linear loads, however, draw currents that are not necessarily sinusoidal. In fact, the current waveform can become quite complex, depending on the type of load and its interaction with other components in the installation. Non-linear loads produce distorted current waveforms in the supply system, and in severe cases this can result in noticeably distorted voltage waveforms. The consequences can include significant energy losses, shortened equipment life and reduced operating efficiencies of devices.

The distortion of the waveform produced by non-linear loads is equivalent to adding components at integer multiples of the supply frequency to the pure supply frequency waveform.

That is, for a 60 Hz supply, the distortion takes the form of additional components at 120, 180, 240, 300, 360 Hz and so on – an example is shown in Figure 1.

These additional components are the harmonics, and in theory, they can go all the way up to infinity. In practice, however, it is rarely necessary to consider harmonics above say, the 50th, which has a frequency of 50 x 60 Hz = 3 kHz and, in most cases, only the lower order harmonics, up to the 15th, will be of importance. Unfortunately, unless they are prevented from doing so, harmonics from a non-linear load will propagate through the supply system causing problems elsewhere.

Knowing that a distorted current waveform can always be represented as a series of superimposed sine waves (using a mathematical procedure known as Fourier analysis) makes it possible to devise a measure of the amount of harmonic distortion pres-

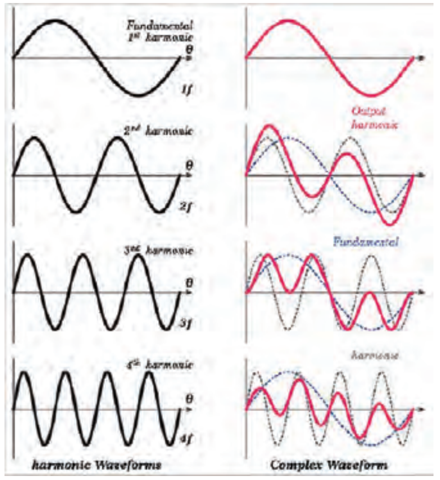


Figure 1: A distorted waveform can be analyzed as multiple sine waves added together

ent in the current in a supply system. This is known as total harmonic distortion (THD)

Harmonic currents have negative effects on almost all items connected to an electrical system; they upset sensitive electronic devices, they increase heating, and they produce mechanical stresses. Among the most common effects of harmonics are computers crashing, lights flickering, electronic components failing in process control equipment, problems when switching large loads, overheating of neutral conductors, unnecessary circuit breaker tripping and inaccurate metering.

While some of these effects could be dismissed as no more than irritants, others such as process equipment failures, can lead to costly downtime. Worst of all are failures of electrical distribution equipment like cables, transformers, motors and standby generators.

Here the replacement equipment is likely to be expensive and today, may only be available on a long lead time. In these cases, both the repair costs and the resulting costs can be substantial. Even if there are no outright failures, the presence of harmonics will cause reduced electrical efficiency within the installation leading to excessive power consumption which you will be paying for.

Eddy current heating in motors and transformers is proportional to the square of the harmonic frequency, so it follows that as the presence of higher order harmonics in the supply system increases, the heating effect will increase even more dramatically. Not only does the generation of heat waste energy – which you are paying for – it also increases the risk of failures of or even fires in wiring, motors, transformers and other distribution equipment.

In addition to the losses that result from heating effects, harmonics in motors can give rise to torsional oscillation of the motor shaft. Torque in AC motors is produced by the interaction between the air gap magnetic field and induced currents in the rotor. When a motor is supplied non-sinusoidal voltages and currents, the air gap magnetic fields and the rotor currents will unavoidably contain harmonic frequency components.

+Sequencing	1, 4, 7, 10, 13
- Sequencing	2, 5, 8, 11, 14
Zero Sequencing	3, 9, 15, 21

These are grouped into positive, negative and zero sequence components. Positive sequence harmonics (1, 4, 7, 10, 13, etc.) produce magnetic fields, and hence torque, rotating in the same direction as the field and torque produced by the fundamental frequency of the supply. Negative sequence harmonics (2, 5, 8, 11, 14, etc.) produce magnetic fields and torque that rotate in the opposite direction. Zero sequence harmonics (3, 9, 15, 21, etc.) do not develop torque, but produce additional losses in the machine.

The interaction between the positive and negative sequence magnetic fields and currents produces the torsional oscillations of the motor shaft, which appears as shaft vibrations. If the frequency of these vibrations coincides with the natural mechanical frequency of the shaft, they become amplified and severe damage to the motor shaft may occur.

Some of the most troublesome harmonics are the 3rd, and odd multiples of the 3rd, i.e. the 9th, 15th etc. called “triplens”. The triplen harmonics on each of the supply phases are in phase with each other so they add rather than cancel in the neutral conductor of a three-phase four-wire system. This can overload the neutral conductor if it has not been sized to allow for the potential presence of harmonics.

While the harmonics usually cannot be removed, since they are generated in the course of the normal operation, they can be prevented from spreading throughout the distribution system.

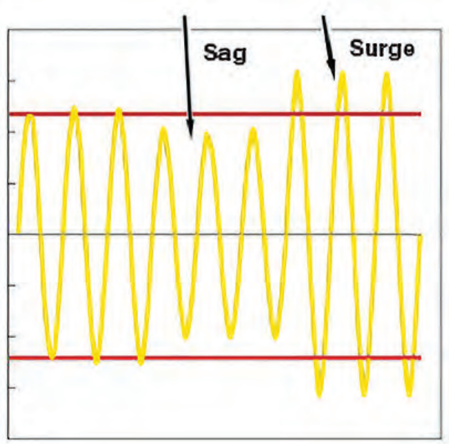
This is usually done by installing passive or active filtering close to the source of the harmonics, and in some cases, by the use of tuned power factor correction equipment. Bringing harmonics under control will eliminate, or at least mitigate, all of the problems we have discussed.

A note of caution is needed. Adopting measures to alleviate harmonics is unlikely to be a once-and-done solution. In today's changing business environment, it's likely that new loads will be connected to your electrical installation. Without measuring, you won't know how these are affecting overall harmonic performance? Therefore, regular monitoring of harmonics is strongly recommended if the benefits of harmonic reduction are to be maintained.

Sags and Surges

If electrical equipment is to operate correctly, it requires electrical energy to be supplied at a voltage (and frequency) that is within a specified range.

In practice, what really matters is it compatible with the loads that are connected to that supply. Sometimes this is not the case, mostly due to voltage sags and surges.



What are voltage sags and surges?

A voltage sag is a sudden reduction in the supply voltage of between 10% and 90%, which typically lasts between 10 ms and 1 minute. The depth of a voltage sag is defined as the difference between the minimum RMS voltage during the sag and the declared supply voltage. Voltage changes that reduce the supply voltage by less than 10% are not considered to be sags.

Voltage sags may be caused by external factors on the supply or internal factors within an installation.

They can be single events that occur at random, or a series of events that repeat in some pattern. In all instances, monitoring and recording the supply voltage over time will show exactly what is happening and help to locate the cause.

External factors are more likely to produce single events and include load switching and fault clearance in the supply network. A similar effect can occur when switching between the line supply and uninterruptible power supplies or emergency back-up generators. Common causes of voltage sags within an installation are the switching of large loads, such as motors, arc furnaces and welding equipment, and the operation of loads with fluctuating current demands. Often voltage sags produced within an installation occur at regular intervals or at particular times.

The effect that sags have on electrical equipment and building occupants varies widely and is dependent on the kind of event and the type of equipment connected to the supply system.

Supply voltage sags can cause particular problems, with varying degrees of severity, for AC induction motors. As the supply voltage to the motor decreases, its speed tends to decrease. Depending on the depth and the duration of the voltage sag, the motor may return to its normal speed when the supply voltage recovers. If the magnitude of the sag or its duration exceed certain limits, however, the motor may stall, or it may be disconnected from the supply by a contractor dropping out or the operation of an under- voltage trip.

For motors fed from a variable speed drive, the drive may shut down to prevent potential motor damage.

Voltage surges are defined as a sudden increase in the supply voltage of 10% or greater for a short period, after which the voltage returns to its normal value. This time period for a surge is generally between 10 ms and 1 minute. Surges are mostly caused by a large load being switched off somewhere on the power supply network or in the local installation.

Although the effects of sags may be more noticeable, voltage surges are often more destructive. Regular and sustained voltage surges can cause insulation degradation in motors because of the increases in current flow and heat generation, with this degradation ultimately leading to premature failure of the motor. Surges can also cause breakdown of components in power supplies and damage to electronic equipment, which is often sensitive to overvoltage.

Fortunately, there are ways to mitigate the effects of sags and surges but an essential first step is always locating the cause of the problem. This is achieved by conducting a site survey, which involves moving around the electrical installation, measuring current and voltage at various locations and using this information to identify the source of the sags and surges.

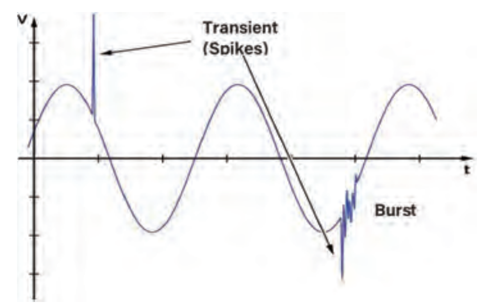
Site surveys are most easily performed with a power and energy logger or power quality analyzer. These instruments can be connected quickly and non-intrusively to distribution panels and other key points within the installation and left in place to gather and record information. In many cases, there is no need to even turn the power off while connecting the instrument.

In many cases the source of the problem will be within your own installation and, once you've identified the equipment causing the sag or surge, you can work on solutions which might include supplying the equipment in question from a dedicated circuit, installing a UPS or, in the case of motors, adding a soft start or variable speed drive to reduce sudden changes in the current the motors draws from.

Transients

Transients – which are also called spikes – can have an effect on equipment and installations that ranges from mildly irritating to extremely damaging and costly. An electrical transient is a very fast, short duration spike in voltage that can be several thousand volts in magnitude. It may be a single event, but it can also come in bursts. The voltage spike produces an increase in current in the load, seen as a current spike, which results in a momentary increase in the energy transferred from the supply to the load. Depending on the magnitude and duration of the transient, the amount of extra energy may be no consequence, or it may be enough to cause serious damage.

Most transients are generated by events external to the installation that is affected. These include as lightning strikes, load switching and fault clearance in the utility company's supply equipment. Because of their high voltages and energy content, transients produced by lightning pose the highest risk of equipment damage and failure, but studies have shown that most transients – more than 80%, are generated within the installation itself.



Lightning induced transients are potentially damaging because the current typically rises quickly to its maximum level within 1 to 10 microseconds, then it decays more slowly in around 50 to 200 microseconds. This rapidly changing current creates electromagnetic radiation (radio waves) that travels outward from the location of the strike. If this radiation encounters an electrical conductor, such as

a power line, a communication line or a metallic pipe, the conductor acts like an aerial and a high voltage – the transient – is induced into it. The conductor doesn't have to be struck directly by the lightning. A strike to the ground near to the conductor can induce large transients.

Other external factors like load switching and fault clearance within the utility supply can generate transients. Load switching transients result from the sudden release of electrical, magnetic, or in the case of rotating machines, mechanical energy stored in a device at the instant it is turned on or off.

A much more frequent source of transients is load switching within an industrial facility. The event that gives rise to the transient could be something like bus transfer is likely to be something simple like a circuit breaker or a contractor opening or closing. Even operating a light switch can create transients and, in every case, the level of transients will be increased if the switching device has faulty or corroded contacts. Office equipment, such as photocopiers and laser printers, are notorious for generating transients, as are HVAC systems. In fact, whenever an inductive or capacitive load is switched on or off, it will almost certainly produce a transient – although a small one, that propagates through the electrical installation.

It is generally the case that the transients generated internally within the installation, which are usually small, are likely to cause slow degradation over time. The much larger transients produced by lightning and the switching of large inductive loads can, however, cause immediate insulation breakdown and subsequently deliver large amounts of energy into the equipment, resulting in failure and, in the worst cases, fire or even an explosion.

The mechanism of these dramatic failures is that when equipment is subjected to a transient that has a voltage higher than the breakdown voltage of the equipment's insulation, a flashover is likely to occur. This flashover is a low impedance electric arc through which current from the supply can flow. With all of the energy of the supply voltage behind it, the strength of the arc and the heat it produces increase almost without limit, creating the risk of fire, explosion and can be life threating.

Traditional electrical equipment is likely to suffer damage only if exposed to large and/or high energy transients, but electronic equipment is much more sensitive and, unless protected, it can be irreparably damaged by comparatively small transients. This is because microcontrollers and similar components rely on thin areas of silicon to insulate them, and such insulation can be damaged by over voltages that would go completely unnoticed in traditional equipment. It's worth noting that transient damage to electronic devices doesn't necessarily result in immediate failure but may reveal itself as a random failure at some future time. Given the present day reliance of almost every aspect of commerce, business and manufacturing on electronic systems, such failures are a real concern, leading to costly downtime and consequential costs.

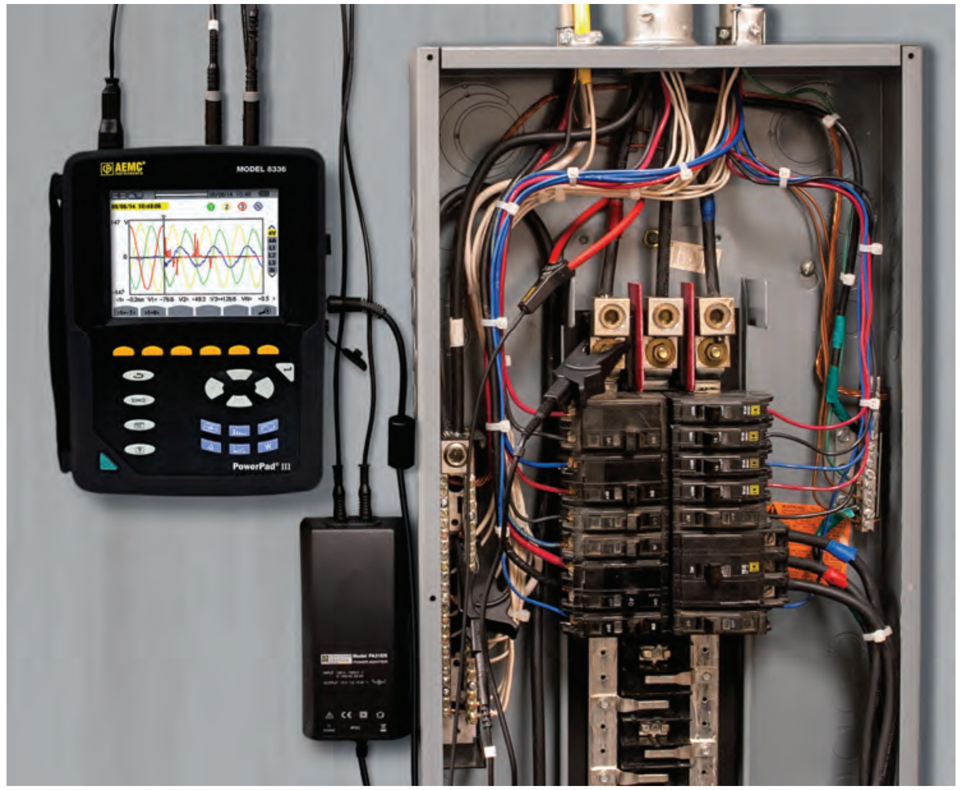
Even when transients do not lead to equipment failure, they can still be disruptive causing computers to crash and lose data, for example, process control systems to shut down unexpectedly and cause ground fault current devices (GFCIs) to trip for no obvious reason.

A wide range of measures are available for providing protection against transients, and selection of the most appropriate type must take into account the voltage, duration and power level of the transients, and the type of equipment that is to be protected. Some types of equipment, such as motors may be designed to withstand transients on a typical supply system without further protection, but this should never be taken for granted. Electronic equipment may also feature integral protection, but this is unlikely to be adequate on its own if no other form of protection is installed on the distribution system of the premises in which it is being used.

It may at first seem unnecessary to provide transient protection for test equipment like multimeters and power analyzers but, in reality, such protection is essential. An electrical installation is just as likely to experience transients while tests are being carried out as at any other time and if the energy released as a result of the transient is enough to destroy an unprotected instrument, the user, who is likely to be close to it or even holding it, may well be injured or worse.

The need for transient protection in instruments is reflected in the international electrical standard IEC 61010 entitled “Safety requirements for electrical equipment for measurement, control, and laboratory use”. This requires test equipment to be able to withstand levels of transients appropriate to the point in the installation where the instrument will be used. (See table)

IEC 61010-1 Transient Overvoltage Tests				
Supply Voltage	Transient Overvoltage			
	CAT I	CAT II	CAT III	CAT IV
150 V	800 V	1500 V	2500 V	4000 V
300 V	1500 V	2500 V	4000 V	6000 V
600 V	2500 V	4000 V	6000 V	8000 V
1000 V	4000 V	6000 V	8000 V	12000 V



IEC 61010 recognizes that externally generated transients will be at their most severe at the point where the supply enters the building and will gradually reduce in magnitude as they travel through the electrical installation, because of the inductance, capacitance and resistance of the wiring and other equipment. Put simply, this means that instruments connected at the point of supply need to be able to withstand transient voltages higher than instruments designed to be connected to fixed wiring within the installation, which in turn need to be able to withstand higher transient voltages than instruments that will be used solely on equipment plugged into outlets. This is summarized in the category (CAT) ratings shown in the table.

CAT I rated instruments can be used for measurements performed on secondary circuits not directly connected to main power. This category is rarely used today. CAT II instruments are suitable for measurements performed on equipment connected to a standard 120/240v power outlets.

CAT III instruments are suitable for measurements performed on the fixed wiring within a building installation, typically near the point of entry which includes distribution panels, circuit- breakers, busbars, junction boxes and industrial equipment.

CAT IV instruments can be used for measurements performed at the source of the low voltage installation which is generally on the utility company side of the meter.

Since instruments with a particular category rating can also be used in lower category applications – a CAT IV instrument can be used in any location within a low-voltage installation – it is often worthwhile investing in instruments with a high CAT rating since this will reduce the risk of an unsuitable instrument being used to carry out a particular task.

Transients can be mitigated using surge protection devices (SPDs), which are designed to prevent voltage spikes and surges damaging the installation wiring, infrastructure and equipment. If an overvoltage occurs, the SPD diverts the resulting excess current flow to earth and limits the voltage to a predetermined maximum value. Depending on circumstances, SPDs can be installed close to the internal source of the transients or close to the loads that need protection, or both.

Three types of SPD are currently available. Type 1 SPDs can discharge partial lightning currents and are used in buildings that are supplied via overhead lines or that have a roof- mounted lightning protection system. Type 2 SPDs are suitable for use in all other types of installation and are often installed at the incoming supply point and/or in sub-distribution panels. Type 3 SPDs have a low discharge capacity and are used to provide localized protection for sensitive equipment. Much more detailed information on the selection and application of SPDs is available on the manufacturers’ websites and reference should also be made to the latest edition of the NEC standards. See NEC article 285.

To decide whether your installation is experiencing problems created by transients, the first action is to use a power quality analyzer and, since transients are almost always intermittent, this needs to be equipped with data logging functionality so that recordings can be made over appropriately long periods of time. A good analyzer will allow limits and alarms to be set to alert you when a significant transient has been detected, you can then examine the data stored by the instrument to gain further information about the form and duration of the transient. This information is invaluable in determining the source.

Electrical Interference

Electrical interference is more formally known as either electromagnetic interference (EMI) or radio frequency interference (RFI). EMI is the more general term, RFI applies only to interference over the band of frequencies used for radio transmissions. However, for this article, the two terms are interchangeable and will be referred to as EMI.

EMI is generally much less harmful than transients. Its effect will typically make equipment malfunction temporarily rather than to cause permanent damage. Even so, equipment malfunctions are often costly and disruptive, so EMI is not a trivial matter.

EMI can come from a variety of sources including radar, TV, radio, mobile phone and microwave transmitters, and from less obvious external sources such as radio signals produced by distant thunderstorms.

External EMI can enter an electrical installation by electro- magnetic induction, electrostatic coupling or conductions. EMI can also be generated by equipment within a facility, although modern appliances and equipment should be man- factored in compliance with electromagnetic compatibility (EMC) standards that minimize the risk of EMI generation.

EMI is most often experienced as noise or hiss on audio equipment.

Other common effects that are less immediately apparent include degradation of the performance of data networks and even completely stoppage of these networks from functioning. This can lead to increased error rates and potentially total loss of data. It’s important to note that EMI can be transmitted by crosstalk between cables that run close together. For this reason, care should always be taken to segregate power and data cables and, where appropriate, to use screened cables.

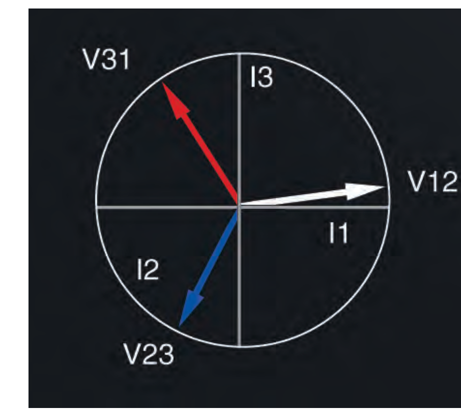
A wide variety of products are available to block EMI and prevent it from entering equipment. These include EMI suppression filters and AC line filters, as well as ferrite cores and microwave absorbers. Such devices are only effective against conducted EMI. Efficient shielding – enclosing sensitive equipment in grounded housings is the best precaution against radiated and induced EMI, so for a complete solution a combination of shielding and filtering is necessary.

If you suspect you’ve got problems with EMI, it’s time to get a power quality analyzer and set it up to monitor the site. EMI will be visibly superimposed on the incoming voltage waveform. It may be intermittent in nature and therefore only revealed by logging the power line for a period of days or weeks.

Voltage Imbalance

Voltage imbalance is a power quality issue that most of the time receives little or no attention. This is unfortunate because an unbalanced supply can have serious consequences. If your business only has single-phase loads, imbalance isn’t an issue for you. If you have any three-phase loads however, you would be well advised to read the rest of this article.

In a balanced three-phase AC power system, the voltages in all three of the phases are equal in magnitude and the phases are 120 degrees apart. In an unbalanced system, the phase voltages are not equal, and/or the phases are not 120 degrees apart. Voltage imbalance is more common than a phase shift and is typically caused by big single-phase loads, such as induction furnaces.



These single-phase loads may be connected between one of the phases and the supply neutral, where they draw power from just one of the three phases, or they may be connected between two phases, where they draw power from two of the three phases. As a result, the three phases are loaded unequally and the voltage on the phase or phases that are heavily loaded will drop. This voltage reduction will be seen as voltage imbalance by all other equipment that are connected to the same supply system.

Uneven distribution of even small single-phase loads across a three-phase system can, if there is enough of them, cause a voltage imbalance. This situation often develops over time when extra equipment or branch circuits are added to a system that was originally balanced during its construction.

Unequal degradation of power factor correction capacitors in a bank or even complete failure of one or more of the capacitors is another source of imbalance, and temporary imbalances can be produced by a fault on one of the phases either within the facility or further back up the supply network.

Having balanced phase voltages is arguably one of the most important requirements for an industrial installation, particularly if it uses three-phase motors, and crucially if they are operating at or near their full load capacity. With a fully loaded motor, unbalanced voltages at the motor terminals can cause a phase current imbalance up to 10 times the percentage voltage imbalance. This means that motors operating on unbalanced supplies must be significantly de-rated, even if the voltage imbalance appears to be relatively minor. Imbalance can also make it necessary to de-rate power cables because of increased I^2 R losses.

According to the "IEEE-1409, Guide for Application of Power" voltage unbalance is defined as the ratio of negative sequence voltage to the positive sequence voltage. Briefly explained, the three phase voltages can be mathematically expressed as a sum of positive, negative and zero sequence components. Positive sequence voltages create a magnetic flux within the motor that rotates in the direction that the motor is intended to rotate, while negative sequence voltages create a flux that rotates in the opposite direction. Since the positive sequence voltages are always much greater than the negative sequence voltages (provided that the motor has been connected correctly) the direction of rotation of the motor will not be affected.

The counter rotating flux caused by negative sequence voltages creates additional heating in the motor windings that may eventually lead to insulation breakdown and premature motor failure. Continuous operation at 10°C (18°F) above the recommended operating temperature can reduce the life of a rotating machine by a factor of two, and reduced motor operating life is almost always disruptive and expensive.

Additionally, solid-state motor controllers and inverters include components that are sensitive to voltage imbalance. Depending on the product, some of these will protect themselves and the motor by shutting down if they detect a significant volt-

age imbalance but, while this safeguards the equipment, the resulting disruption can still be costly. In less sophisticated products that don't automatically shut down, voltage imbalances are a common cause of reduced life.

Uninterruptible power supplies (UPSs) and inverter supplies also operate with reduced efficiency when presented with unbalanced supply voltages, often producing increased ripple on the DC output and, in many cases, increased harmonic currents in the supply system.

Voltage imbalance can have so many harmful effects, that it is covered by national and international standards. IEEE 112 and IEC 60034-1, for example, imposes a 1% negative phase sequence voltage limit on the supply feeding machines.

Fortunately, the measurement of voltage and load (current) balance, and therefore the identification of imbalance, is easily achieved using a power and energy logger (such as AEMC's PEL103). With a PEL connected at the incoming supply, the loading across the phases for the whole installation can be monitored over time to see how it varies during the normal operating day or week or longer. The PELs Power and Energy logger can be quickly moved around the installation, non-intrusively connected, and used to measure individual equipment or circuit loads and voltages to evaluate the balance condition throughout the installation. They can then be reconnected to the incoming supply for ongoing monitoring not only of voltage balance but also of other important supply parameters such as harmonics and power factor.

To reduce voltage imbalances and their effects, there are two key steps you should take. The first is to use separate circuits for large single-phase loads and connect them as close as possible to the source of the supply. This will ensure that the single-phase load does not cause a voltage drop on any wiring used by other equipment. The second step is to ensure that all single-phase loads, large and small are distributed evenly across all three phases. These two steps can save a lot of headaches and expense.

Power Factor

Like voltage imbalance, power factor is rarely considered to be a power quality issue, but it should be because poor power factor is very common, it means that businesses pay large sums of money for energy they don't and can't use, and it's relatively easy and inexpensive to correct.

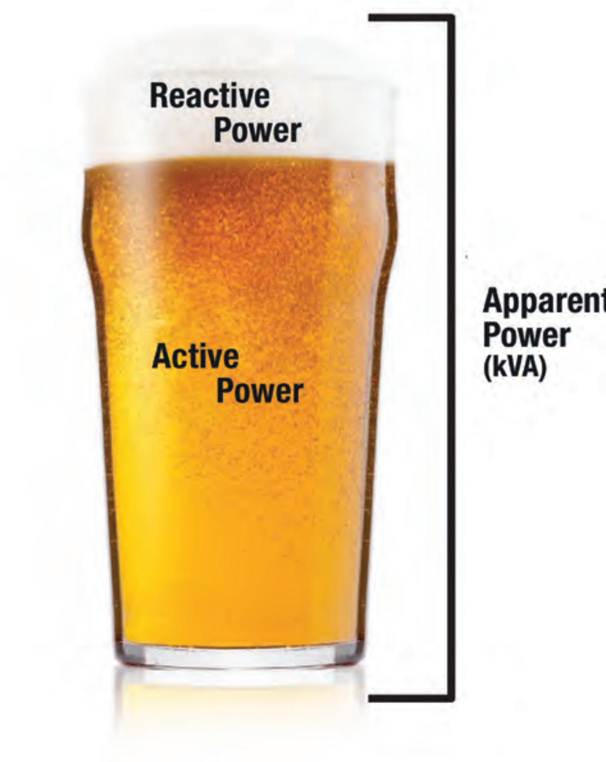
Poor power factor is not a new issue; for decades, experienced engineers looking after industrial and commercial installations have put measures in place to ensure that their facilities had a good power factor. But today, fewer and fewer sites have such engineers to take care of them and, as a result, power factor gets forgotten and the inevitable result is needlessly increased energy bills.

What actually is power factor, and why is it so important?

The key to the explanation is that some types of electrical equipment used in industrial and commercial applications consume a certain amount of reactive power in addition to the real (or active) power they need to do the job for which they are intended. These are often inductive devices – that is, devices that incorporate coils of wire as part of their construction. Examples are motors, induction heaters, arc welders, compressors and most types of fluorescent lighting. It's important to understand that the reactive power doesn't do anything useful as far as the user of the equipment is concerned.

Technically speaking, reactive power is the vector difference between the real or active power used by a device, and the total power it consumes, which is known as the apparent power. Simply stated, power factor is the ratio of the real power to the apparent power.

A device with a low power factor increases energy losses in the electrical distribution system, so energy suppliers penalize industrial customers that have a poor power factor. A device with a poor power factor draws more current than a device that's doing an equal amount of useful work but has a high (or good) power factor. Higher currents increase energy losses in the electrical distribution system, resulting in energy suppliers penalizing customers that have a poor power factor by charging them more for their electricity due to the fact that they need to be able to supply additional energy that would not show on the revenue meter.



Speaking less technically, this scenario can be made easier to understand by likening it to a typical glass of beer. If you order a glass of draught beer, the whole glass you pay for is equivalent to the apparent power. But take a closer look – that beer has got a frothy head on it! The beer is the part you really want, and that's equivalent to the active power, while the head, which makes no contribution to your refreshment, is equivalent to reactive power. A glass full of beer, with no head, would represent a power factor of 1 with no reactive power at all. In reality, that's usually impossible to achieve and a power factor of 0.95 (corresponding to less than 5% froth) or better is usually considered acceptable.

So far, so good, but if electrical equipment inherently consumes active power, what can be done about it? Fortunately, it is possible to correct for power factor by adding a power factor correction (PFC) system. This usually takes the form of capacitors connected at the main distribution panel, or sometimes at other locations.

Many sites will already have some form of power factor correction (PFC) but as mentioned earlier, it is always a install and forget solution. If more equipment is installed on a site, or the type of equipment used on the site is significantly changed, the PFC system may no longer be adequate. Also, capacitors used for PFC can degrade over time and would eventually need to be replaced.

In fact, it is not uncommon for industrial installations to be operating with high levels of reactive power giving power factors of between 0.7 and 0.8. This is unnecessary and costly since measuring power factor is not at all difficult. It can be readily measured using portable test instruments, or alternatively, can be permanently monitored in real-time with constantly displayed values, along with a multitude of other useful parameters including voltage, current and energy consumption.

While specification of a PFC system to reduce reactive power requires knowledge of several factors including the voltage level and typical usage of the reactive loads on-site, the usage profile across the site, and the power quality required by the on-site loads, all of these are easily measured and/or calculated. And a properly designed PFC system will be a fraction of the cost of the savings it delivers.

The simplest form of PFC involves installing capacitors, but it is worth shopping around and taking expert advice to find a system that will accurately suit your particular requirements. If a single machine has a poor power factor, capacitors can be connected in parallel with it, so that they compensate for the poor power factor whenever the machine is switched on. Alternatively, if the power factor of a site is permanently poor and no single item of equipment is solely responsible, fixed PFC can be connected across the main power supply to the premises.

In more complex applications, where many machines are switched on and off at various times, the power factor may be subject to frequent change. In this case it is advisable to employ expert advice for the best solution.

Conclusion

We hope that this article has succeeded in explaining the sometimes-complex subject of power quality and clarified why it is considered it to be important. If you're a typical business owner or manager, there's absolutely no doubt that you pay great attention to the quality of products and services you buy for your business, and it should be the same for the power and energy you consume. After all, energy bills are probably a significant part of your outgoings.

We've shown that power quality can be degraded in many ways, and such degradation often has inconvenient and costly consequences. Just as important, however, we've shown that power quality problems are easy to detect with the right monitoring and data logging equipment. In most cases once the problems have been identified; convenient and affordable solutions are available.

Test instrumentation designed to monitor and identify power quality issues will easily pay for themselves in no time both with savings on your energy bill and prolonged operating life of your equipment. ❑

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