This information covers HARMONICS quite well.

William Hinton's collection

Note: Phaseback VSGR family of solutions are not included in this collection as they provide a multi-dimensional solution to Harmonics, Arc Flash, Surges, & other Power related problems.

The resistance of the copper windings in an ac induction motor is not immune to the inherent inefficiency of the motor because the energy conversion process—electric to mechanical—in a ac magnetic induction motor is a source of significant heat from several sources. The heat-stimulated increase in windings resistance results in the commensurate increase in energy to achieve the same level of useful work. The extent to which the energy contained in harmonic frequencies superimposed on the electric power supply to an ac induction motor further decreases its efficiency. Reducing the harmonic content of the voltage supplied to an electric motor will increase the efficiency of the motor. The increase in motor temperature due to the harmonics would decrease the life of the motor.

- Positive sequence 4, 7, 10, 13, …—harmonics that contribute to the forward ro- tation of the motor
- Negative sequence 2, 5, 8, 11, ...—harmonics that contribute to the reverse rota- tion
- Zero sequence 3, 6, 9 12, …—harmonics that do not contribute to rotation.
  All harmonics cause a rise in temperature with the lowest causing the greatest rise. In all cases the losses were greater and the temperature rose as the harmonic distortion factor increased. Harmonics increase motor temperature by increasing the heat generated internally in the motor while producing the same useful work.

Electric power system waveform distortion decreases induction motor efficiency through different mechanisms. Increased motor heating due to unnecessary current in windings causes increased winding resistance and added losses. Unsynchronized electromagnetic forces caused by distortion force the motor to work harder to generate the same power output. Efficiency can be improved by removing power system waveform distortion.

Motor Temperature Reduction

Motors operated on a VFD tend to run warmer than when they are operated on pure 60hz, such as in an across-the-line stator application. The reason is that the output waveform of the VFD is not pure 60hz,, but rather it contains harmonics which are currents flowing at higher frequencies. The higher frequencies cause additional watts loss and heat to be dissipated by the iron of the motor, while the higher currents cause additional watts loss and heat to be dissipated by the copper windings of the motor. Typically the larger horsepower motors (lower inductance motors) will experience the greatest heating when operated on a VFD.

It is possible to reduce the motor operating temperature by actually reducing the harmonic content in the output waveform. A five percent harmonic reduction will typically reduce the motor temperature by 20 degrees Celsius or more.

If we consider that the typical motor insulation system has a "Ten Degree C Half Life" (Continual operation at 10 degrees C above rated temperature results in one half expected motor life), then we can see that motor life in VFD applications can easily be doubled.

Motor Noise

Because the carrier frequency and harmonic spectrum of many Pulse Width Modulated (PWM) drives is in the human audible range, we can actually hear the higher frequencies in motors which are being operated by these drives. A five percent harmonic reduction will virtually eliminate the higher order harmonics (11th & up) and will substantially reduce the lower order harmonics (5th & 7th). By reducing these harmonics, the presence of higher frequencies is diminished and thus the audible noise is reduced. Depending on motor size, load, speed, and construction the audible noise can typically be reduced from 3 - 6 dB with a five percent harmonic reduction. Because we humans hear logarithmically, every 3dB cuts the noise in half to our ears. This means the motor is quieter and the remaining noise will not travel as far.

Motor Efficiency

Because harmonic currents and frequencies cause additional watts loss in both the copper windings and the iron of a motor, the actual mechanical ability of the motor is reduced. These watts are expended as heat instead of as mechanical power. When harmonics are reduced motor watts loss are reduced. The motor is able to deliver more power to the load at greater efficiency. Utility tests conducted on VFD's with and without harmonic filters have documented efficiency increases of as much as eight percent (at 75% load) when the harmonic filters were used.

Isolation Transformers:

There are three basic functions of isolation transformers, as follows.

- To change or adjust system voltage levels
- To act as a separately derived power source
- To provide electrical isolation

The requirement for this type of equipment is more frequent in larger commercial and industrial facility distribution systems. Additionally, isolation transformers assist in isolating harmonics that are common when a Delta-to-Wye configuration is used. These secondary harmonics can actually increase by as much as 75% due to the WYE secondary.

Isolation transformers do not address or provide protection against voltage anomalies such as sags, surges, undervoltages, or overvoltages. In fact, because of the inherent nature of a transformer, voltage variations impressed on the primary winding induce current in the transformer’s secondary winding. This in turn develops a secondary voltage. Further, the inherent nature of a transformer may result in the generation of transient activity.

ZERO sequence components of fundamental and 5th and 7th do not exist, however 3rd and 9th harmonic have a zero sequence component. These components are NOT TORQUE PRODUCING components because they do not produce a rotating field. These produce a “standing wave” and are essentially dissipated in the leakage flux of the machine, or are carried by the neutral conductor of the 3 phase system. The harmonics, multiples of 3, are called TRIPLENS (or triplets), and contribute to a large neutral current, or cause large leakage fluxes in the machine. They are not tolerable for efficiency purposes. The 5th, 11th etc... produce

NEGATIVE torques, opposing the fundamental, and hence reduce the efficiency of the mechanical to electrical conversion ratio. The 7th 13th etc... produce POSITIVE torques, and hence one would think that they are desired, however, they also produce high losses (remember 49 time more eddy losses compared to the fundamental), and usually these losses are much larger than the torque conversion ability of the machine. Harmonic interaction in the Induction machine: If the stator produces 5th and 7th harmonics with the fundamental, the induced currents in the rotor will also have these components. However, the torque is produced by the interaction of fluxes in the air gap. The fundamental stator field (rotating in the + direction by definition) will combine with the 5th harmonic of the rotor. Because the rotor flux is induced, its direction of rotation is inverse from the stator flux, and because in the stator it has a negative sequence, in the rotor it will produce a positive sequence. 1st and 5th will therefore have the same sequence component, and will result in 6th harmonic flux in the air gap. Conversely, the 7th harmonic in the stator (positive) will induce a 7th harmonic flux in the rotor which will rotate in the opposite direction, therefore 1st in the stator and induced 7th in the rotor will have combined fluxes at the 6th harmonic also. The 6th harmonic produces no torque, but it OSCILLATES at 6 times the fundamental frequency, therefore producing TORSIONAL TORQUE OSCILLATIONS. These can be very stressing on the shaft of the machine and due to material fatigue will damage the machine.

It is imperative to limit the harmonic currents in a rotating machine !

Harmonics and their effects on power distribution systems.

Harmonics in the electrical distribution system are the by-products of modern electronics. They are especially prevalent where there are large numbers of personal computers, printers, copiers, medical test equipment, fluorescent lighting and adjustable speed drives. Harmonics do no useful work; they degrade the level of power quality and efficiency in a commercial building or industrial facility.

Harmonics are currents or voltages with frequencies that are integer (whole number) multiples of the fundamental power frequency. If the fundamental frequency is 60Hz, the third harmonic is 180Hz, the fifth 300Hz, etc. Harmonics are created by non-linear loads, so-called because the current is not drawn as a smooth sine wave. When electronic equipment turns AC to DC, it draws current in pulses. These pulses cause distorted current wave shapes that are rich in harmonics. Electronic equipment will act as harmonic current generators. When these harmonic currents flow back into other parts of the power system they can also distort the voltage waveform which becomes non-sinusoidal. The distorted voltage can than effect other loads that share a transformer or branch circuit with the original harmonic load.

A word about power quality and productivity.

Deregulation, Power Quality, Harmonics, Power Factor, are all terms that have become more common in the last 2 decades, because of the new non-linear technologies that have become accepted for their working efficiency. Variable Frequency Drives, Switching Power Supplies, Computer technology are examples of these non-linear loads that have; 1. Made productivity gains unsurpassed by previous innovations. 2. Made power quality concerns surface because of the way these loads use current. Putting it all together can be confusing, but when designing or applying power quality solutions, you will be well rewarded through improved productivity, improved MTBF's, and improved overall system reliability.

The Harmonic Problem...

Any device with non-linear operating characteristics can produce harmonics in your power system. If you are currently using equipment that can cause harmonics or have experienced harmonic related problems, capacitor reactor or filter bank equipment may be the solution.

Harmonic distortion and related problems in electrical power systems are becoming more and more prevalent in electrical distribution systems.

Problems Created by Harmonics

- Excessive heating and failure of capacitors, capacitor fuses, transformers, motors, fluorescent lighting ballasts, etc.
- Nuisance tripping of circuit breaker or blown fuses
- Presence of the third harmonic & multiples of the 3rd harmonic in neutral grounding systems may require the derating of neutral conductors
- Noise from harmonics that lead to erroneous operation of control system components
- Damage to sensitive electronic equipment
- Electronic communications interference

The following is a discussion of harmonics; the characteristics of the problem; and a discussion of our solution.

Origins of Harmonic Distortion

The ever increasing demand of industry and commerce for stability, adjustability and accuracy of control in electrical equipment led to the development of relatively low cost power diodes, thyristors, SCRs and other power semi-conductors. Now used widely in rectifier circuits for U.P.S. systems, static converters and A.C. & D.C. motor control, these modern devices replace the mercury arc rectifiers of earlier years and create new and challenging conditions for the power engineer of today.

Although solid state devices, such as the thyristor, have brought significant improvements in control designs and efficiency, they have the disadvantage of producing harmonic currents.

Harmonic currents can cause a disturbance on the supply network and adversely affect the operation of other electrical equipment including power factor correction capacitors.

We are concentrating our discussions on harmonic current sources associated with solid state power electronics but there are actually many other sources of harmonic currents. These sources can be grouped into three main areas:

1. Power electronic equipment: Variable speed drives (AC VFDs, DC drives, PWM drives, etc.); UPS systems, rectifiers, switch mode power supplies, static converters, thyristor systems, diode bridges, SCR controlled induction furnaces and SCR controlled systems.
2. Arcing equipment: Arc furnaces, welders, lighting (mercury vapor, fluorescent)
3. Saturable devices: Transformers, motors, generators, etc. The harmonic amplitudes on these devices are usually insignificant compared to power electronic and arcing equipment, unless saturation occurs.

Waveform

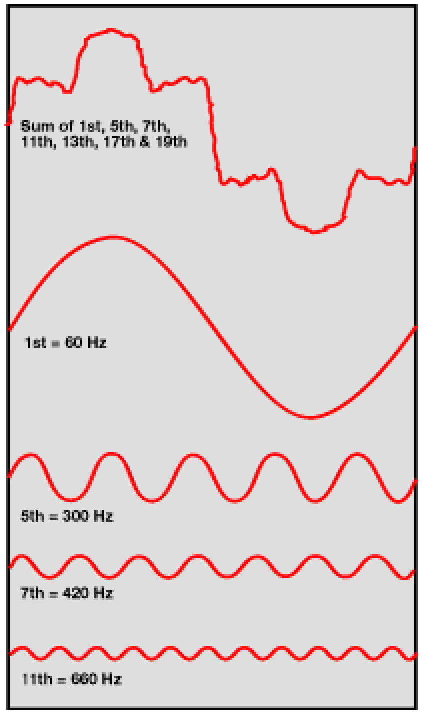
Harmonics are sinusoidal waves that are integral multiples of the fundamental 60 Hz waveform (i.e., 1st harmonic = 60 Hz; 5th harmonic = 300 Hz). All complex waveforms can be resolved into a series of sinusoidal waves of various frequencies, therefore any complex waveform is the sum of a number of odd or even harmonics of lesser or greater value. Harmonics are continuous (steady-state) disturbances or distortions on the electrical network and are a completely different subject or problem from line spikes, surges, sags, impulses, etc., which are categorized as transient disturbances.

Transient problems are usually solved by installing suppression or isolation devices such as surge capacitors, isolation transformers or M.O.V.s. These devices will help solve the transient problems but will not affect the mitigation of low order harmonics or solve harmonic resonance problems.

Harmonic Content

Thyristor and SCR converters are usually referred to by the number of DC current pulses they produce each cycle. The most commonly used are 6 pulse and 12 pulse.

ORDER OF HARMONIC	TYPICAL PERCENTAGE OF HARMONIC CURRENT	
	6 Pulse	12 Pulse
1	100	100
5	20	-
7	14	-
11	9	9
12	8	8
17	6	-
19	5	-
23	4	4
23	4	4



There are many factors that can influence the harmonic content but typical harmonic currents, shown as a percentage of the fundamental current, are given in the above table. Other harmonics will always be present, to some degree, but for practical reasons they have been ignored.

Harmonic Overloading of Capacitors

The impedance of a circuit dictates the current flow in that circuit.

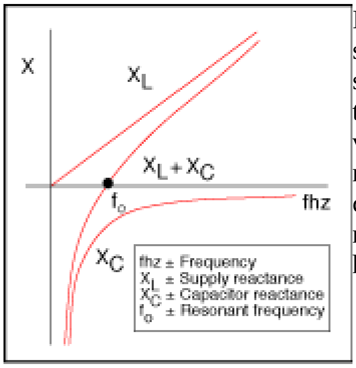
As the supply impedance is generally considered to be inductive, the network impedance increases with frequency while the impedance of a capacitor decreases. This causes a greater proportion of the currents circulating at frequencies above the fundamental supply frequency to be absorbed by the capacitor, and all equipment associated with the capacitor.

In certain circumstances, harmonic currents can exceed the value of the fundamental (60 Hz) capacitor current. These harmonic problems can also cause an increased voltage across the dielectric of the capacitor which could exceed the maximum voltage rating of the capacitor, resulting in premature capacitor failure.

Harmonic Resonance

The circuit or selective resonant frequency is reached when the capacitor reactance and the supply reactance are equal.

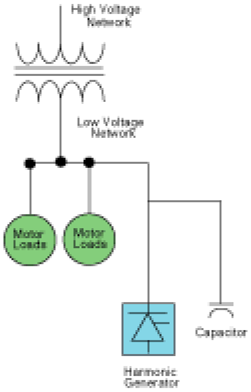
Whenever power factor correction capacitors are applied to a distribution network, which combines capacitance and inductance, there will always be a frequency at which the capacitors are in parallel resonance with the supply.



If this condition occurs on, or close to, one of the harmonics generated by solid state control equipment, then large harmonic currents can circulate between the supply network and the capacitor equipment. These currents are limited only by the damping resistance in the circuit. Such currents will add to the harmonic voltage disturbance in the network causing an increased voltage distortion. This results in a higher voltage across the capacitor and excessive current through all capacitor components. Resonance can occur on any frequency, but in general, the resonance we are concerned with is on, or close to, the 5th, 7th, 11th and 13th harmonics for 6 pulse systems.

Avoiding Resonance

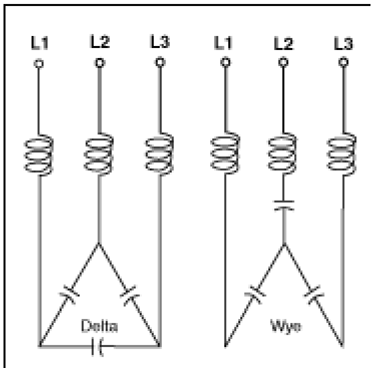
There are a number of ways to avoid resonance when installing capacitors. In larger systems it may be possible to install them in a part of the system that will not result in a parallel resonance with the supply. Varying the kvar output rating of the capacitor bank will alter the resonant frequency. With capacitor switching there will be a different resonant frequency for each step. Changing the number of switching steps may avoid resonance at each step of switching.



Overcoming Resonance

If resonance cannot be avoided, an alternative solution is required. A reactor must be connected in series with each capacitor such that the capacitor/reactor combination is inductive at the critical frequencies but capacitive at the fundamental frequency. To achieve this, the capacitor and series connected reactor must have a tuning frequency below the lowest critical order of harmonic, which is usually the 5th. This means the tuning frequency is in the range of 175 Hz to 270 Hz, although the actual frequency will depend upon the magnitude and order of the harmonic currents present.

The addition of a reactor in the capacitor circuit increases the fundamental voltage across the capacitor. Therefore, care should be taken when adding reactors to existing capacitors.



Detuned Capacitor/Reactor Systems

Reduction of Harmonic Distortion

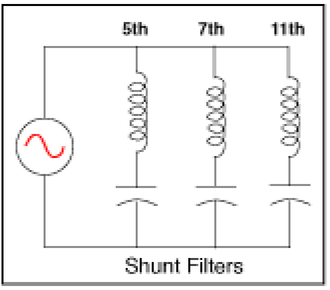
Harmonic currents can be significantly reduced in an electrical system by using a harmonic filter.

In its basic form, a filter consists of a capacitor connected in series with a reactor tuned to a specific harmonic frequency. In theory, the impedance of the filter is zero at the tuning frequency; therefore, the harmonic current is absorbed by the filter. This, together with the natural resistance of the circuit, means that only a small level of harmonic current will flow in the network.

Types of Filters

The effectiveness of any filter design depends on the reactive output of the filter, tuning accuracy and the impedance of the network at the point of connection.

Harmonics below the filter tuning frequency will be amplified. The filter design is important to ensure that distortion is not amplified to unacceptable levels. Where there are several harmonics present, a filter may reduce some harmonics while increasing others. A filter for the 7th harmonic creates a parallel resonance in the vicinity of the 5th harmonic with magnification of the existing 5th harmonic; therefore, a 7th harmonic filter requires a 5th harmonic filter. Consequently, it is often necessary to use a multiple filter design where each filter is tuned to a different frequency. Experience is extremely important in the design of such filters to ensure:



Shunt Filters

(a) the most efficient and cost effective solution is selected;

(b) no adverse interaction between the system and the filter.

Load Alteration

Whenever load expansion is considered, the network is likely to change and existing filter equipment should be evaluated in conjunction with the new load condition. It is not recommended to have two or more filters tuned to the same frequency connected on the same distribution system. Slight tuning differences may cause one filter to take a much larger share of the harmonic distortion. Or, it may cause amplification of the harmonic order which the equipment has been designed to reduce. When there is a need to vary the power factor correction component of a harmonic filter, careful consideration of all load parameters is necessary.

Harmonic Analysis

The first step in solving harmonic related problems is to perform an analysis to determine the specific needs of your electrical distribution system. To determine the filter requirements, it is necessary to establish the impedance of the supply network and the value of each harmonic current.

GLOSSARY

Alternating current (AC): An electrical system in which voltage polarity and current flow alternates direction on a regular basis. Your home is an example of a system that is powered by AC.

Amp: A unit of electrical flow. In a water system, the flow of millions of water molecules would be expressed in terms of gallons per minute. In an electrical system, the flow of millions of electrons is expressed in terms of amps or amperes.

Apparent Power: The amount of power that is apparently consumed by a load. Apparent power is measure in VA or volt-amperes and is calculated by measuring the current consumed by the load and multiplying it by the voltage powering the load.

Common Mode Voltage: A voltage of any amplitude or frequency that is measured between the phase conductor and the ground conductor or the neutral conductor and the ground conductor. Neutral to ground voltage is a common mode component that frequently causes computer system malfunction. Neutral to ground voltages should always be limited to .5 volts (one half of one volt) or less.

Constant Voltage Transformer: Maintains a relatively constant output voltage for variations up to 20% in the input voltage. CVT’s are frequently a ferro-resonant style of transformer in which the voltage is regulated by means of current stored in a magnetic field. CVT’s are generally high impedance devices that are unsuitable for most modern computers with switch mode power supplies.

Current: The "flow" of electricity. Much like water, a current will follow the path of least resistance. As a result, electric current always finds the easiest path to ground. Current is measured in amps or amperes.

Dedicated Circuit: An obsolete method for providing clean, noise free power to a computer system. A dedicated circuit is one in which dedicated phase, neutral, and safety grounding conductors are run continuously from a distribution panel to an electronic load. The conductors may service only the dedicated load and the phase conductor must have its own circuit breaker. Furthermore, the dedicated conductors must run in their own dedicated metallic conduit or raceway with no other conductors present. The neutral and ground conductors may not be "daisy chained" or shared with any other circuit. The ability of dedicated circuits to guarantee a noise and disturbance free environment is insufficient for the high processing speeds, low operating voltages, and mission critical nature of modern technology.

Direct current (DC): An electrical system in which current flows in one direction only. A battery is an example of a direct current source.

Dip: See "Sag".

Disturbance: Any departure from the nominal values of the power source. Disturbances can include transients, electrical noise, voltage changes, harmonics, outages, etc.

Drop: A slang word sometimes used to describe voltage sags or under voltages.

Flicker: A voltage variation of short duration but long enough to be noticeable to the human eye as a light flicker.

Frequency: In an AC system, the value of the voltage sinewave rises from zero to a maximum, falls to zero, increases to a maximum in the opposite direction, and falls back to zero again. This would describe one complete cycle. The number of complete cycles occurring in one second is called frequency. The General Conference on Weights and Measures has adopted the name hertz (abbreviated Hz) as the measurement of frequency. In North America, the frequency is 60 Hz. In Europe and most of Africa and Asia it is 50 Hz.

Glitch: A slang term for a voltage transient or voltage variation that causes equipment to misbehave..

Grounding Conductor: The physical conductor connecting the chassis of an electrical or electronic device to the electrical system's grounding means. Sometimes referred to as the safety ground, this conductor may be a green insulated conductor, a bare copper wire, conduit, gutter or raceway. The purpose of the grounding conductor is provide a low impedance pathway for fault current in the event of a short circuit so that a circuit may be quickly de-energized to prevent a fire hazard or electrocution.

Grounded Conductor: Refers to the neutral conductor of the electrical system, which is bonded to the facility's utility field earth reference in order to reference the facility electrical system to ground.

Harmonic: A whole multiple of the basic power frequency. On a 60 Hz system the 2nd harmonic is 120 Hz, the third harmonic is 180 Hz, the fourth is 240 Hz and so on.

Harmonic Distortion: The alteration of the normal voltage or current wave shape (sine wave) due to equipment generating frequencies other than the standard 60 cycles per second.

Impedance: Impedance is the opposition offered by a material to the flow of an electrical current in an AC electrical system. Impedance has two parts - resistance and reactance. Impedance is measured in ohms.

Interruption: See "Outage".

Inverter: Device that converts direct current (DC) power into alternating current (AC) power.

Isolated Ground: An insulated equipment grounding conductor that is run in the same conduit as the supply conductors. This conductor is insulated from the metallic raceway and all ground points throughout its length. An isolated grounding conductor may only be connected to the grounding of the electrical system as a point where the facility neutral (grounded conductor) is bonded to ground. An example would be at the service entrance or at a distribution sub-transformer.

Isolation Transformer: A device that electrically separates and protects sensitive electronic equipment by buffering electrical noise and re-establishing the neutral-to-ground bond. By virtue of the neutral-to-ground bond, isolation transformers eliminate neutral-to-ground voltage - one type of common mode disturbance.

Line Conditioner: A device that provides for the electrical power quality needs of the connected electrical or electronic load. In the case of a linear power supply, a line conditioner might be a voltage regulator. In the case of a switch mode power supply, a line conditioner might be an isolation transformer with a noise filter and surge diverter. In the case of a simple electrical device like a motor, a line conditioner might be as rudimentary as a surge diverter. The term line conditioner is frequently misused. It must be understood that not all line conditioners function alike, and the capabilities of a line conditioner must be matched to the power quality needs of the connected load.

Linear Power Supply: A power supply which converts AC power into the DC power that is needed to operate an electronic circuit. In a linear supply, the AC voltage is first stepped down, then rectified, and then regulated using a series regulation device. Linear supplies obtain their name from the fact that there is a linear relationship between the value of the AC sine wave voltage and the power supply's consumption of current from the AC circuit. Linear power supplies are generally less efficient because the series regulator dissipates large amounts of heat in the process of producing and regulating the DC output voltages. In addition, linear mode power supplies may require well regulated AC input voltage. One benefit of linear power supplies is that they produce little electrical noise.

Mission Critical Load: Devices and equipment identified as important or essential to the safety of personnel or the economic health of a business.

Momentary Outage: A brief interruption in power commonly lasting between 1/30 (2 cycles) of a second and 3 seconds.

Nines of Reliability: The reliability of an electrical system is a combination of both its availability (freedom from outages) as well as it's quality (freedom from disturbances). Reliability is expressed in percentages. 99% would be expressed as two 9s of reliability. 99.9% would be three 9s reliable, 99.99% would be four 9s reliable and so forth. The average well managed electrical system in North America has about three 9s of reliability. In a 24 x 7 operation, that translates into about 88 hours per year in which the availability and quality of the electrical system are unsatisfactory to reliably power a mission critical electronic load.

Noise: An unwanted high-frequency electrical signal that alters the normal voltage pattern (sine wave). Noise may be either high amplitude or low amplitude.

Normal (Nominal) Voltage: The normal or contracted voltage assigned to a system for determining voltage class.

Normal Mode Voltage: Any voltage (other than fundamental 50 Hz or 60 Hz) that is measured between the phase conductor and the neutral conductor in a single phase system or between any two phase conductors of a three phase system. Normal mode voltage can be any amplitude or frequency. Normal mode noise voltages can interfere with the reliable operation of a computer system or degrade and destroy components. Normal mode power disturbances should be limited to 10 volts or less.

Ohm: A unit of resistance and impedance.

Ohms Law: The relationship between voltage, current and resistance in a DC circuit. If two values are known the other can be calculated. This relationship is expressed many different ways. The basic relationship is voltage (V) is equal to current (I) multiplied by resistance (R). Ohm’s law must be applied in a modified way to AC circuits. AC circuits have impedance rather than resistance. Impedance causes AC circuits to exhibit power factor, which must be factored into any calculations

Outage: Complete loss of electrical power.

Overvoltage: An increase in voltage outside the normal voltage levels (10% or greater) for more than one minute.

Phase Relationship: The timing relationship between voltage and current. If voltage and current cross through zero in a cycle at the same time they are said to be in phase. Phase differences are expressed in degrees. A cycle is 360 degrees. In a totally capacitive circuit, current leads voltage by 90 degrees. In a totally inductive voltage leads current by 90 degrees. In a circuit that is purely resistive, voltage and current are in phase.

Power Factor: The ratio between Watts and Volt-Amperes. This ratio is generally expressed as a decimal fraction. A power factor of 1.00 is unity.

Reactance: Reactance has two components, capacitive reactance and inductive reactance. The values of reactance are determined by the values of the individual capacitor or inductor as well as the frequency of the current flowing in the circuit.

Real Power: The amount of power that is actually consumed by the load. Real power is measure in watts and is calculated by measuring the current consumed by the load and multiplying it by the voltage powering the load and then multiplying by the power factor of the load.

Rectifier: A device that converts alternating current (AC) power to direct current (DC) power.

Reactive power: Reactive power is the difference between apparent power and real power. It is calculated by subtracting real power from apparent power. Reactive power is measured in VAR (volt-amps reactive) or kVAR (kilovolt/amps reactive)

Resistance: The opposition offered by a material to the flow of a steady electrical current in a DC circuit. Resistance is measured in ohms.

Sag: Any short-term (less than 1 minute) decrease in voltage.

Spike: See "Transient".

Standby Generator: An alternate power supply usually driven by a gas or diesel engine.

Surge: A sudden dramatic increase in voltage that typically lasts less than 1/120 of a second.

Surge Protective Device (SPD): A device that is designed to limit instantaneous high voltages. Also known as a surge suppressor, surge arrestor and transient voltage surge suppressor (TVSS). These units are satisfactory for reducing the amplitude of catastrophic events. However, they function by diverting excess voltage to the safety ground of the electrical system. In the process they create a common mode disturbance which can disrupt the function of microprocessor based electronic systems.

Swell: Any short-term (less than one minute) increase in voltage.

Switch Mode Power Supply: A power supply technology in which the AC power is converted into DC power for use by an electronic system. SMPS technology uses switching transistors operating at very high speed to keep a capacitor reservoir sufficiently charged to produce the appropriate DC voltage needed by the electronic circuit. SMPS technology is very efficient because it does not utilize the "lossy" series regulator found in the linear power supply. Current is consumed from the circuit only when the charge state of the capacitor reservoir requires it. SMPS technology is "constant power" in that when line voltage decreases, the supply’s current consumption increases and when line voltage increases, current consumption decreases. SMPS technology is relatively immune to voltage regulation issues. However, the technology does not employ a stepdown transformer on the front end, which means that it does not satisfactorily isolate the electronic system from the electrical supply. SMPS technology produces electrical noise as a result of the high speed function of the switching transistors.

Transient: See "Surge"

True Power: See "Real Power"

TVSS: See "Surge Protective Device"

Undervoltage: A decrease in voltage outside the normal voltage levels (10% or greater) for more than one minute.

Uninterruptible Power Supply (UPS): A system designed to automatically provide power in the event that utility power is interrupted. A UPS may be standby, line interactive, or on line. A UPS is not necessarily a power conditioner, and care must be taken to ensure that the UPS provides all the power quality requirements that are needed.

Volt: A unit of electrical pressure. In a water system pressure might be expressed as pounds per square inch. In an electrical system, the pressure that causes electrons to move is called voltage. The voltage found in most homes is 120 and 240 volts. Businesses will typically utilize voltage at 120 and 208, or 277 and 480 volts.

Volt-Ampere (VA): The product of volts times amps. A kilovolt-ampere (kVA) is equal to one thousand volt-amperes. VA is also known as apparent power.

Voltage: The electrical "pressure" that creates the flow of current.

Voltage Regulator: A device that maintains output within a desired limit despite varying input voltage. These devices usually provide little to no protection against voltage transients or noise.

Watt (W): A unit of power equal to the product of the value of current of one ampere flowing in phase with the pressure of one volt. A kilowatt is a thousand watts. Watts are an expression of real or true power.

Watt-Hour (Wh): A unit of energy equal to the power of one watt for one hour. A kilo-watt hour is a thousand watt-hours.

Waveform Distortion: Any power quality variation in the wave shape of the voltage or current.

References

Applied Energy LLC. Website http://www.applied-energy.us or http://www.phaseback.com

Transformers and Motors: A single-source reference for electricians by George Patrick Schultz 1989

Electric Power Distribution System Engineering by Turin Gonen 1986

Handbook of Transformer Design and Applications second edition by William M. Flanagan 1992

Elements of Power System Analysis fourth edition by William D. Stevenson, Jr. 1982

Handbook of Electric Power Calculations third edition by H. Wayne Beaty 2001

IEEE (Gray Book) Recommended Practices for Electric Power Systems in Commercial Buildings 1974

Westinghouse Electrical Maintenance Hints second printing 1974

Jalilian A., Gosbell, V.J., and Perera, B.S.P. Performance of a 7.5kW Induction Motor Under Harmonically Distorted Supply Conditions. Electrical and Computer Engineering, 2000 Conference on. Vol. 1 (2000) IEEE Catalog Number 00TH9492: 355–359.

Inan, Aslan and Attar, Ferit. Yildiz The Life Expectancy Analysis for an Electric Motor Due to Harmonics.

Electrotechnicial Conference, 1998, MELECON 98, 9th Mediterranean. Vol. 2

(May 1998): 997–999.

Lee, Ching-Uin, Lee, Wei-Jen, Wang, Yen-Nien, and Gu, Jyh-Cherng. Effects of Voltage Harmonics on the Electrical and Mechanical Performance of a Three-phase Induction Motor. Industrial and Commercial Power Systems Technical Conference (May 1998). IEEE Catalog Number 98CH36202: 88–94.

Muckhopadhyay, S.C., Pal , S.K., Roy, D., Bose, S. Software Aided Derating and Performance Prediction of Cage-rotor Induction Motors under Distorted Supply Conditions. Power Electronics, Drives and Energy Systems for Industrial Growth, 1996, Proceedings of the 1996 International Conference on. Vol. 1 (January 1996): 452–457.

Emaniel, A.E. Estimating the Effects of Harmonic Voltage Fluctuations on the Temperature Rise of Squirrel-cage Motors. IEEE Transactions on Energy Conversion. Vol. 6 (March

1991): 162–169.

HARMONIC (orig.-7/31/02)