

# PowerKure - Approach for Energy Savings Through Power Quality

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## Abstract

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Power Quality Definition: Power quality is the degree to which both the utilization and the delivery of electric power affect the performance of electrical equipment and cost of operation.

Utilities in Canada are very good at supplying bulk power.

Highly sensitive devices such as computers and solid-state controlled equipment are susceptible to power line disturbances. It is necessary to refine and improve power quality to eliminate unwanted disturbances, deterioration and breakdowns of these and all electrical devices. Most of the power quality issues are generated from within the facility or from the close surrounding area. Utility disturbances are usually from voltage fluctuation (sags / swells) or reclosures. Incidents of damage or deterioration to customer-owned electrical equipment resulting from abnormal voltage conditions, current imbalance, surges/transients, harmonics, losses, power factor, power interruptions, and phase loss add up to unwanted expenditures. Power Quality anomalies result in increased electric bills; excessive maintenance and equipment failure. They have long been a concern to consumers as well as electrical utilities.

This paper briefly quantifies the effect of the above undesirable conditions from an operation/maintenance and economic point of view. A remedy for such anomalies is offered through the use of an integrated system called PowerKure™. It is used for commercial, institutional and industrial facilities that will not only correct the anomalies but reduce the hydro bills from 3% to 25%, guaranteed.

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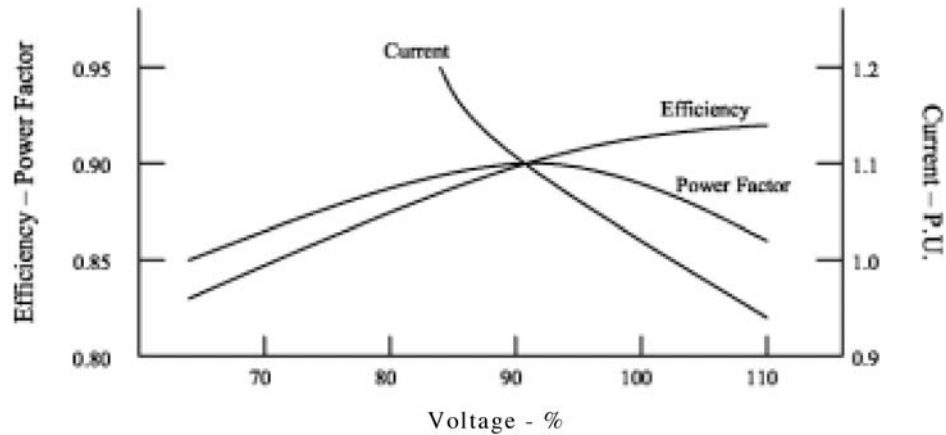
## Voltage Stability

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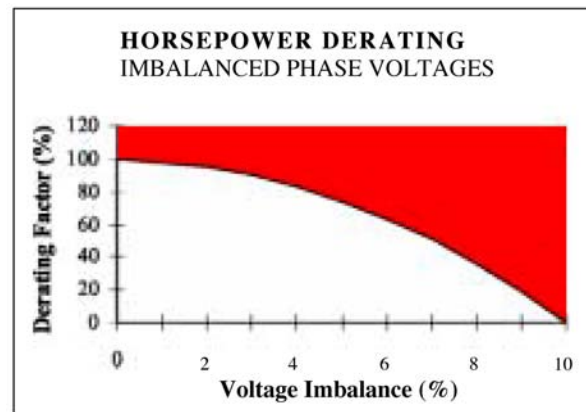
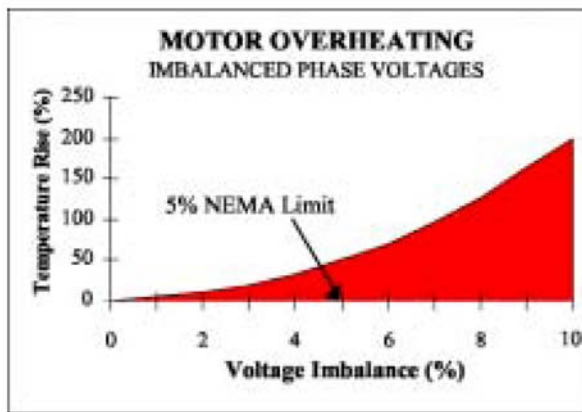
Over-voltage, under-voltage, and voltage fluctuations are among major electrical problems, which presently exist in industry, commercial and institutional facilities. Voltage regulation is essential due to ever changing load characteristics and supply voltage requirements. The continuous variations in impedance and X/R, (reactive/resistive) will result in possible unacceptable voltage instability. Unbalanced voltage supply to motors occurs more often than commonly known, which causes numerous electrical, mechanical, and energy problems.

Voltage unbalance can be extremely detrimental to the proper operation and expected life of three-phase motors. When line voltages supplying an induction motor are not equal in magnitude, a multitude of problems occurs. Unbalanced voltages on three-phase motors produce large unbalanced currents, overheating of the motor, shorter insulation life, excessive losses, and wasted energy. Also, significantly unbalanced line currents make the problem of providing adequate overload protection more difficult.

Unbalanced voltages occur quite frequently in three-phase distribution systems, usually as a result of the connection of a large single-phase load to two of the three phase conductors. Comparatively speaking, we have experienced three-phase systems, that you will normally find one phase drawing more or less than the remaining two phases. Occasionally, the voltage unbalance may be due to errors in distribution transformer tap connections, an unstable utility voltage supply, poor connections in the power supply, open delta transformer systems, a problem within the motor itself, or improper functioning of capacitor banks. When line voltages applied to a three-phase motor are not exactly the same, the unbalanced currents cause a “negative voltage sequence” to occur. These negative voltage sequences have a rotation that is opposite to that of balanced voltages.



Unbalanced voltage produces a corresponding negative-sequence flux causing unbalanced currents in excess of those under balanced voltage conditions. It is important to note that excessive current creates excessive heat, which in turn, shortens insulation life; insulation breakdown is permanent. In the phase with the highest current, the percentage increase in temperature rise will be approximately two times the square of the percentage voltage unbalance. Thus, a 3% voltage unbalance will increase temperature rise about 332 or 18%. Such an unbalance could also result in electromechanical vibration, leading to bearing failures. In addition, noise and vibration will be particularly severe on high rpm motors.



**PowerKure™** with its multiple stage Ladder Logic configuration, connected in most cases in parallel, will provide a number of variable impedance stages containing RLC (R=Resistive L=Inductive C=Capacitive) network to assist in the desired voltage stabilization with respect to each electrical distribution's Q factor.

## Load Balancing

In today's industry, based on production and operation requirements, there are number of equipment and machinery suppliers with products of various characteristics, functions, and requirements. Variations of the same product by different suppliers are often so unique to that product in magnitude that in most cases its characteristics from no-load to full load can not be perfectly matched by another supplier. Such uniqueness can certainly affect impedance, X/R (reactive/resistive), and its effect on the facility's electrical distribution.

Most important influential factor contributing towards three-phase imbalance can be credited to single phase loads. Non-linear operation schedule of single-phase load in a facility and their distribution among the three-phase system will determine degree of phase imbalance in that facility. As was

explained, when line voltages applied to a three-phase motor are not exactly the same, the unbalance currents cause a “negative voltage sequence” to occur. These negative voltage sequences have a rotation that is opposite to that of balanced voltages. Unbalanced voltage produces a corresponding negative-sequence flux causing unbalanced currents in excess of those under balanced voltage conditions. It is important to note that excessive current creates excessive heat, which in turn, shortens insulation life; insulation breakdown is permanent. In the phase with the highest current, the percentage increase in temperature rise will be approximately two times the square of the percentage voltage unbalance. Thus, a 3% voltage unbalance will increase temperature rise about 332 or 18%. Such an unbalance could also result in electromechanical vibration, leading to bearing failures. In addition, noise and vibration will be particularly severe on high rpm motors.

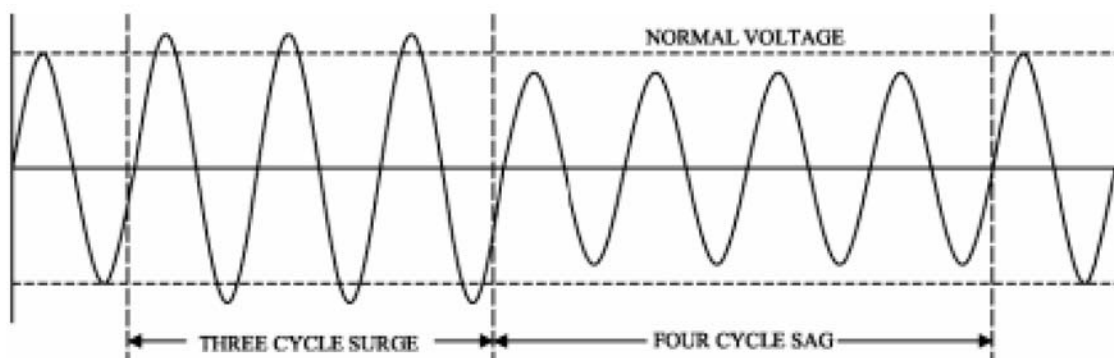
**PowerKure™** with its multiple stage Ladder Logic configuration, connected in most cases in parallel, will provide number of variable impedance stages containing RLC network with components normally connected in a delta formation for each stage to minimize losses while the controller responds based on the load’s X/R (reactive/resistive) and load factor with each stage response of not to exceed 50 seconds to assist in the desired three phase balanced load, as viewed from the primary supply side.

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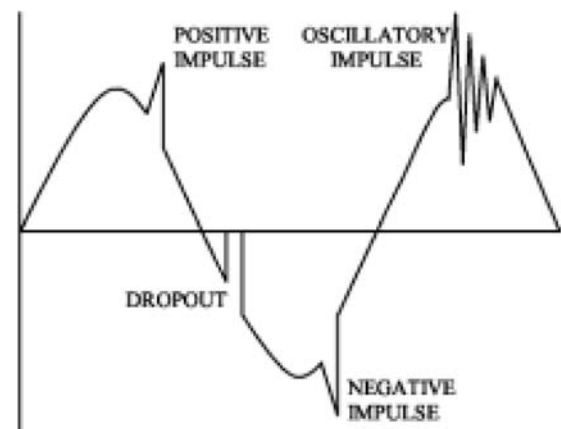
## Surges and Transients

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A surge is not an impulse or a spike. A surge is a transient condition where a series of peak sine-wave voltages exceed the set standard voltages for a period of time, from about one half a cycle to possibly several hundred cycles. This might also be defined as from 8 milliseconds to 2.5 seconds.



As a result, common surge suppressors or surge protectors may not suppress surges at all. These devices are designed to suppress impulses of a high magnitude. An impulse is a disturbance of the voltage waveform for duration of less than roughly 1 millisecond. An impulse may be additive or subtractive in nature and it may have a ringing or oscillatory characteristic. Some of the more common terminologies associated with this term are: spike, notch, transient, whisker, and glitch.



In a related matter, a sag is identical to a surge except that the peak sine-wave voltage has decreased from the set standards for a period of time, rather than increasing. Some of the more commonly used terminologies associated with this term are flicker and dips. A long-term under-voltage condition that is actually planned by the utility company, or is the result of excessive loading, is called a brownout. A blackout is a widespread loss of utility power, either accidental or planned. Voltage impulses resulting from heavy loads being switched on and off within the electrical distribution system such as large motors, HVAC systems, switch arcing, fuse blowing, breakers clearing, and arc furnaces, to name a few of traditional culprits, are among undesirable disturbances.

A comprehensive study by IBM revealed the following results:

Type of Disturbance	Number of Disturbances	Days Between Disturbances
Under-voltage	1569	
Over-voltage	103	32.2
Outages	65	51.0
Switching Disturbances	2831	1.2
Impulses	1676	2.0
Total	6244	0.5

If we divide the total number of disturbances by the number of monitoring days, we get an alarming average figure. We can expect 2 events of one type or another every day.

Most circuits can withstand a high voltage for a short time. The shorter the time becomes, the higher the tolerable voltage becomes. How quickly an arrestor can eliminate a surge from a circuit depends on four factors: the magnitude of the voltage, the quantity of the charge, the speed at which the arrestor starts conducting, and the conductivity of the arrestor. Common arrestors, because of their inherent characteristics, have some resistive load by which they perform clipping. Based on their energy ratings, in Joules, the device can easily be destroyed without any indications for possible future protection. This phenomenon is among the most deceiving, costly, and least understood behavior by those who use them, which is the most common cause of failure and breakdown of computers, controls, and more sensitive devices.

**PowerKure™** behavior in such applications can be designed to withstand high current, high energy with extremely fast and unlimited response to surges. In addition, due to PowerKure™ damping factor, most, if not all the energy will be absorbed to be released based on the system's phase sequence. In case of massive magnitude of surges or transients, PowerKure™ components are fully protected with breakers and with continuous diagnosis system identifying operation of each internal component.

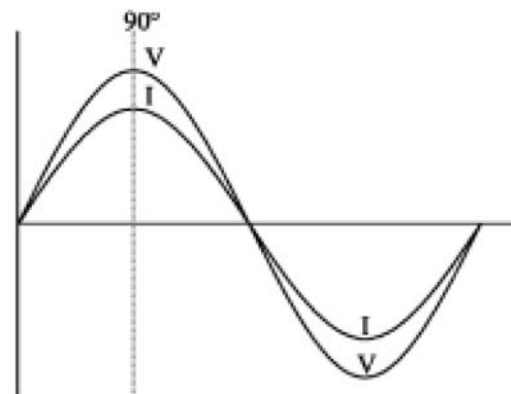
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## Power Factor

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Power factor is the ratio of Actual Power used in a circuit to the Apparent Power delivered by a utility. Actual Power is expressed in Watts (W) or Kilowatts (KW); Apparent Power in volt-amperes (VA) or Kilovolt-amperes (KVA):

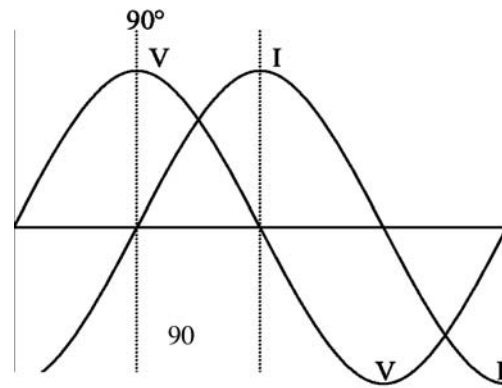
$$\text{Power Factor} = \text{Cos} = \frac{\text{Actual Power (KW)}}{\text{Apparent Power (KVA)}}$$



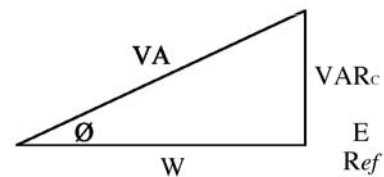
*In a purely resistive circuit, peaks occurs at the same time*

In inductive loads, such as motors and transformers, current is used to create magnetic forces, which produces the required torque in motors and the transformed voltage in transformers. These magnetic forces oppose changes in current levels. In an AC system, where the supply voltage is constantly being varied due to magnetic load requirements, the current lags the voltage. The phase angle between current and voltage is referred to as the Power Factor. Ultimate system power factor is unity (100%). The lower the power factor, from the unity, the further current will lag behind the voltage; which results from magnetic current increase. Most common and economical solution to remedy low power factor adopted by most engineers used to be static capacitors; and in isolated cases some still do. This practice, just to improve power factor, is usually economical, but carries potentially damaging side effects. With today's computers and electronically controlled and sensitive equipment and machinery, application of capacitors can be a major liability. Concerns are vastly due to cost effectiveness with respect to most electrical rate structures, but mainly from failure of equipment and machinery and plant downtime. Power factor correction capacitors (PFCC) can also overheat due to harmonic distortion on line voltage in the power system. Since the impedance of a capacitor decreases as the frequency of the applied voltage increases, excessive current can flow through the capacitor. Capacitors can also form a resonant circuit with inductive elements in the system, which will create a measurable increase in the voltage across the capacitor and similar loads. Static capacitor's inherent characteristics are:

- A. Over-voltage
- B. Harmonics magnification, resonance, and overheating
- C. Capacitive reactive increase in the system
- D. Leading power factor under low-load or no-load
- E. Susceptibility to surges and transients
- F. Power Factor



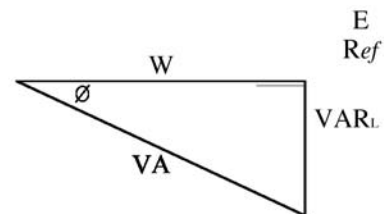
*In a purely inductive circuit, the current waveform lags the voltage by 90.*



*(a) Leading PF (Circuit Capacitive)*

$$\frac{\phi = 0^\circ E}{W = VA} \quad \text{Ref}$$

*(b) Unity PF (circuit resistive)*



*(c) Lagging PF (Circuit Inductive)*

Power triangles for leading, unity, and **PowerKure™** microprocessor based control, operating based on Ladder Logic principle, will insure continuous monitoring of system's reactive power/power factor. An automatic system, equipped with variable high and low adjustments, whose control employs data input other than that of the system's reactive current component will perform during its corrective process in a damped response to an inductive or relative manner.

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## Harmonics

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Linear loads, such as purely resistive loads, carry current waveforms that are the same shape as the applied sinusoidal voltage waveform. Nonlinear loads, such as wave - chopping DC loads, carry current waveforms that are non-sinusoidal. While traditional linear loads allow voltages and currents of the fundamental frequency (60HZ) to appear in power systems with little or no harmonic currents, nonlinear loads can introduce significant levels of harmonics into the system.

A harmonic is simply an integer multiple of the fundamental frequency. The third harmonic in a 60 HZ system is a 180 HZ current; the fifth harmonic is a 300 HZ current, and so on.

Harmonics in the power system combine with the fundamental to form distorted wave shapes. The amount of distortion is determined by the frequency and amplitude of the harmonic currents. A nonlinear load draws current in abrupt pulses rather than in a smooth sinusoidal fashion. These pulses cause harmonic currents that, in turn result in voltage distortion and harmonics, causing even more current harmonics in various parts of the power system.

Computers are among contributors to the problem of nonlinear loads. Like most other electronic office equipment, computers are equipped with a diode/capacitor-type power supply. This type of power sine wave AC waveform and, as a result, generates large amounts of third harmonic currents (180 HZ). Other sources of harmonic currents include variable-speed motor controls, solid-state heating controllers, and any other devices that do not draw current in a sinusoidal fashion.

The effects of nonlinear loads and their resultant harmonic currents can show up several areas of the power system, most commonly in transformers and neutral conductors, but also in motors, generators, and capacitors. Electronic ballasted light fixtures also generate harmonics. For fluorescent lighting fixtures with conventional magnetic ballasts, the third harmonic content is typically in the range of 13% to 20% of the fundamental 60 HZ frequency. Electronic ballasts generate an even higher third harmonic component, as high as 80%. Overheated transformers (K Factor), motors, and standby generators that are exposed to significant levels of harmonic currents can suffer serious increases in operating temperature. In addition, excessive current in the neutral conductors not only overheats the conductors, possibly causing damage to insulation, but also can be reflected back into the 3-phase transformer winding as a circulating current, causing additional heat. Power Factor Correction Capacitors (PFCC) can also overheat due to harmonic distortion on line voltage in the power system. Since the impedance of a capacitor decreases as the frequency of the applied voltage increases, excessive current can flow through the capacitor. Capacitors can also form a resonant circuit with inductive elements in the system, which will create a measurable increase in the voltage across the capacitor. Lighting ballast capacitors are also susceptible to heat caused by high-frequency currents; frequent failures of this type are indicative of the presence of harmonics in the system. Harmonics can be a cause of inefficient distribution of power, power line carrier (PLC), e.g. Clocks and Energy Management Systems (EMS). Finally, harmonics can cause utility meters, KW Demand and KWH consumption, to register false readings.

**PowerKure™** microprocessor based control, operating based on ladder logic principle, will insure continuous monitoring of system's reactive power/power factor (X/R), and threshold current. An

automatic system, equipped with variable high and low adjustments, whose control employs data inputs other than that of the system's reactive current component will perform during its corrective process in a damped or tuned RLC network response to an indicative or relative manner.

In addition, PowerKure™ can provide manually controlled specific single-harmonic tuned filters, as well as, multiple-harmonic tuned filters to remedy all harmonic conditions present in industry and commerce.

PowerKure™ is an integrated system. Most PowerKure™ systems are equipped with a microprocessor base control, capable of monitoring voltage, current and power factor in conjunction with threshold current/harmonics. The microprocessor, following adjusted settings, will control components through a damped circuitry to achieve the design criteria by using contactors and in some cases SCR's.

PowerKure™ can be equipped with a number of active and passive components such as SCR's contactors, resistors, capacitors, inductors/reactors, MOV's, (Metal Oxide Varistor) controls, monitoring/control circuitry, enunciator lights and fuses. These components are designed and fabricated in a system, which its principle of operation is based on Ladder Logic. Design criteria for each PowerKure™ is solely dependent on customer's electrical distribution characteristics and economics considerations.

**PowerKure** standard features address: voltage stability, three phase imbalance, surge/transients, broadband harmonics, distribution/system losses, power factor, and KVA release; which have been topic of this paper.

In addition, PowerKure™ offers optional features that can be designed and made to address the following problems:

- A. Specific harmonics filtering - filters specific or multiple harmonics of any magnitudes;
- B. Brownout protection - maintains nominal voltage during the occurrence of temporary, momentary low line voltage;
- C. Phase synthesis - Maintains continuous three phase supply on the occurrence of either a momentary loss or complete failure of one phase. This feature will allow power to be maintained until the three-phase supply voltage is restored.
- D. Momentary supply failure protection - maintains continuous supply during intermittent voltage interruptions.

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## Conclusion

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**PowerKure** comprehensive approach is to engineer and designs each system that will enhance and improve the client's electrical system. This approach will achieve actual power reduction and costs savings from 3% to 25%, along with power quality benefits.

Acknowledgement: Power Quality Definition: Ontario Hydro Power Quality Reference Guide