Power Quality and the Hershey System

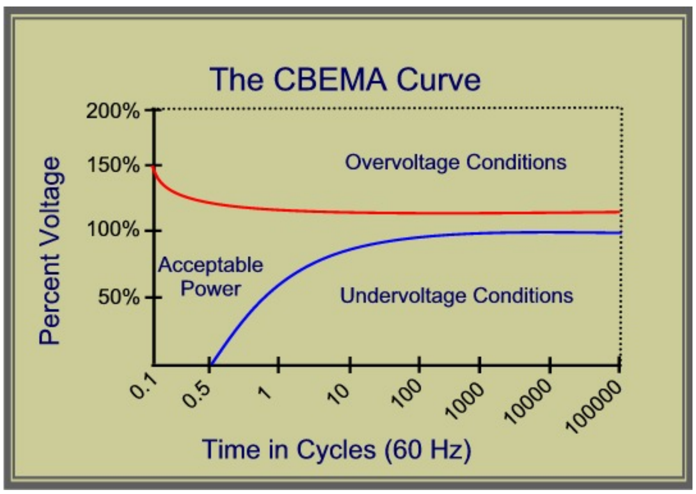
The following is intended to provide an overview of power quality problems that exist in industry today and the methods that the Hershey Power Conditioning System employs to solve these problems. The benefits gained by solving these problems can be significant to a manufacturing operation. In fact, a study recently conducted by EPRI estimated that the average overhead feeder experiences over 40 power quality disturbances each year. These disturbances were determined by EPRI to have some impact on process equipment on the plant floor that translates directly into lost revenues. Even a modest estimate of $2,500 per event translates to $100,000 in annual losses caused directly or indirectly by power quality disturbances.

By seeking to solve these power quality problems, a facility will realize the following cost-saving benefits:

1. Increased production reliability (less downtime, decreased scrap material)
2. Decreased maintenance and replacement costs for machinery
3. Energy Savings (kW, kWh, and reduced power factor penalties)

Finally, it should be noted that this discussion does not cover the area of wiring and grounding as it is outside the scope of the Hershey System. Nonetheless, a proper grounding and wiring scheme for a facility is an integral step in minimizing power quality problems.

Over/Undervoltage, Short-Term Voltage Fluctuations, Voltage Imbalance, Intermittent Supply Failures



Voltage irregularities are one of the greatest power quality issues facing industry today. In fact, about 95% of the problems revealed in electrical networks stem from voltage problems.

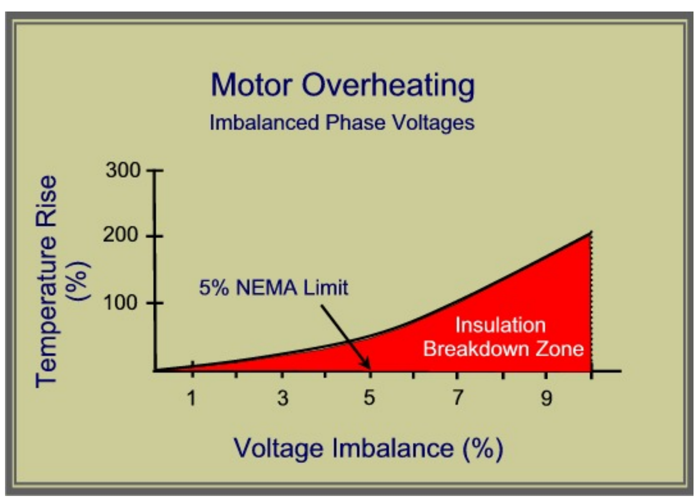
Over/Undervoltage: Technically speaking, an over/undervoltage condition is reached when the voltage exceeds/lags the nominal voltage by 10% for more than 1 minute. Both of these conditions result in voltage that falls outside the acceptable power envelope as defined by the CBEMA Curve pictured here.

Short-Term Voltage Fluctuations: Short duration voltage events can also occur such as transients (both impulsive and oscillatory), sags/dips and swells. Although shorter in duration (by definition they are all shorter than 1 minute), these events can reach a magnitude that falls outside the acceptable power envelope as shown in the CBEMA curve.

When this happens, events above the upper asymptote will lead to insulation breakdown, overvoltage tripping and over excitation. Events below the lower asymptote may cause loads to drop out altogether.

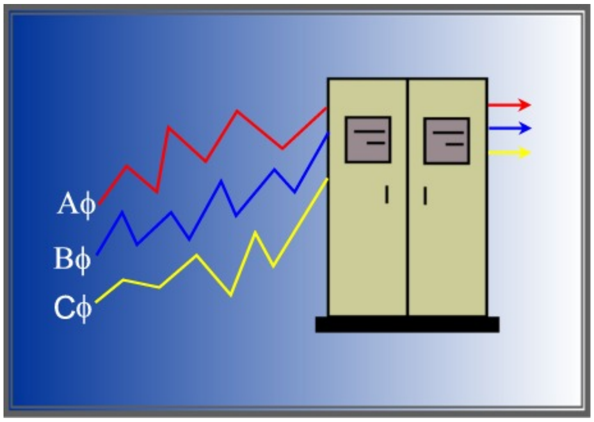
Voltage Imbalance: Voltage imbalance is most often seen as a result of single-phase motors installed on a three-phase circuit. It is measured by averaging the voltages on the 3 phases, and then measuring the maximum deviation for any 1 phase from that average. Voltage imbalance that exceeds 2% is detrimental to reliable long-term 3-phase motor operation.

Furthermore, voltage imbalance generates unwanted heat in motors. This, in turn, results in wasted energy, insulation breakdown, and improper/inefficient motor operation. As we can see from the opposing motor overheating graph, a 5% voltage imbalance would result in a 50% increase in temperature. Per NEMA limits, a motor should not be operated with a voltage imbalance at or above 5%.



Intermittent Supply Failures: Short duration intermittent supply failures can last anywhere from .5 cycles up to 1 minute and can be caused by a number of occurrences such as supply system faults (caused by lightning or other natural phenomena), equipment failures, or malfunctions in control equipment. These intermittent supply failures can be very costly to industry and can have the following adverse effects on a distribution system:

- Voltage control relay tripping
- Phase imbalance relay tripping
- Production line shutdowns
- Loss of microprocessor memory
- Jogging, pinching and stalling of motors
- Loss of control equipment



The Hershey Solution: The standard Hershey system will boost the secondary voltage on a given electrical network and in so doing, protect it against undervoltage conditions and intermittent voltage sags that may occur on that network. Furthermore, the Hershey System utilizes a lower impedance value to trap transients and swells and prevents them from harming sensitive equipment on the plant floor.

Unlike MOV's or other surge suppressors that have limited joules/second capacity and simply channel the absorbed energy to ground, the Hershey System is able to absorb an infinite number of transients and/or swells and will re-circulate the swell or transient energy 120° out of phase. This produces energy savings in addition to protecting sensitive equipment.

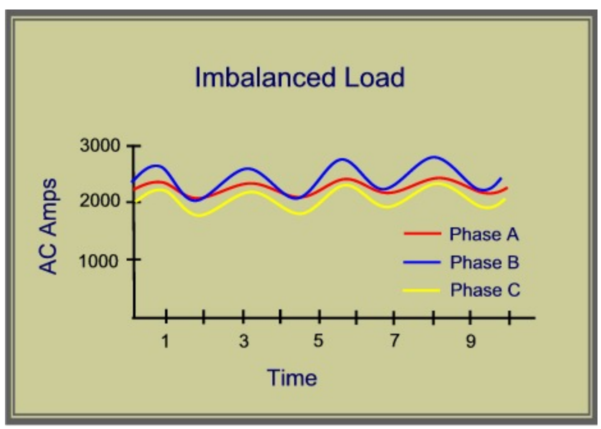
The standard Hershey system is also designed to balance the voltage across the 3-phases to within 2%. This provides a very stable electrical network for long-term, efficient operation of plant equipment.

Finally, the Hershey System can also be designed to provide protection against intermittent supply failures. This option, also called the "1-Second Carry Through", provides 59/60 cycles of ride through power to a distribution system. Note that the system is designed with increased capacitance to handle this situation, and will weigh significantly more than the standard system.

Imbalanced Currents

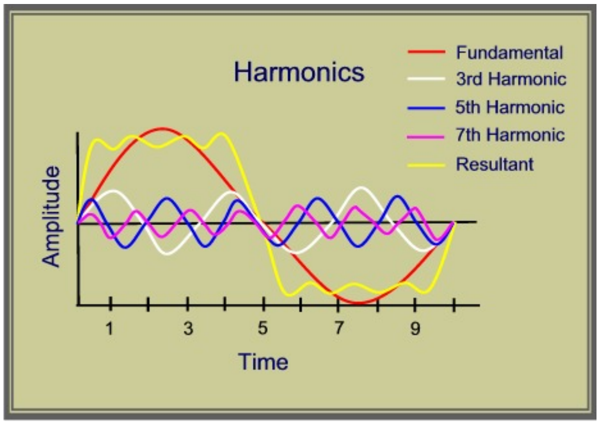
Imbalanced currents: Imbalanced currents often arise when single-phase loads are employed unevenly on a 3-phase distribution system. When the imbalance approaches 10%, the following problems may surface in an electrical distribution system:

- Negative Voltage Sequence.
- Circulating currents.
- Increased current in neutral conductor.
- Increased Neutral-to-Ground voltage.
- Overheating of motors (insulation breakdown).
- Reduced motor efficiency.
- Motor bearings failures.
- Increased maintenance of equipment and machinery.
- Wasted energy / higher electric bills - KWD and KWH.
- Wasted investment and operating capital.



The Hershey Solution: The standard Hershey system will balance the 3 phases electrically based upon X/R and the impedance of the system, Z, in order to ensure that this 10% limit is not exceeded throughout the electrical networks. In addition, the standard Hershey system will reduce the current across all 3 phases by 30-40% thereby reducing the line losses (I^2Z) and accounting for a portion of the guaranteed energy savings.

Harmonics, Triplen Harmonics, 5^{th} & 11^{th} Harmonics



Harmonics: Harmonics by definition are a steady state distortion of the fundamental frequency (60 Hz). Harmonic distortion of current occurs when sinusoidal voltage is applied to a non-linear load (ex. electronic ballast, PLC, adjustable-speed drive, arc furnace, any ac/dc converter). The result is a distortion of the fundamental current waveform. This distortion occurs in integer multiples of the fundamental frequency (60 Hz). Hence, the 2^{nd} Harmonic has a frequency = 2 x 60 = 120 Hz, the 3^{rd} Harmonic = 180 Hz and so on. Voltage distortion, on the other hand, is generated indirectly as result of harmonic currents flowing through a distribution system.

It is important to note that the vast majority of harmonic currents found in a distribution system are odd-order harmonics (3^{rd}, 5^{th}, 7^{th}, etc.). Secondly, more often than not, the sources of the harmonic currents in a distribution system are the loads in operation within that facility. Interestingly, these are frequently the types of loads that are the most sensitive to distortion in the current and/or voltage.

Triplen Harmonics – The triplen harmonics are defined as the odd multiples of the 3^{rd} harmonic (ex. 3^{rd}, 9^{th}, 15^{th}, 21^{st} etc.). Triplen harmonics are of particular concern because they are zero sequence harmonics, unlike the fundamental, which is positive sequence. The consequence of this fact is that the magnitude of these currents on the 3 phases are additive in the neutral. This can lead to very large currents circulating in the neutral, and unless the neutral is sufficiently oversized this can present a fire hazard. These currents can also circulate in the transformer causing significant overheating there too. Single-phase power supplies for equipment such as electronic ballasts and PCs are the most significant source of Triplen harmonics.

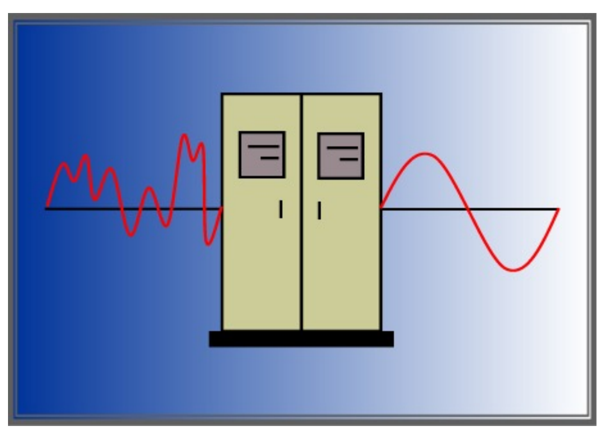
5^{th} and 11^{th} Harmonics – The 5^{th} and 11^{th} harmonics are also of particular concern to industry today. Although the 5^{th} harmonic is much more prevalent, both have a negative sequence. This means that when distorted voltage containing the 5^{th} or 11^{th} harmonic is applied to a 3-phase motor, it will attempt to drive the motor in reverse, creating a negative torque. In order to compensate for this negative torque, the motor must draw additional fundamental current. This, in turn, can cause overheating and/or the tripping of over-current protection devices. 6-Pulse adjustable speed drives are a major source of the 5^{th}, 7^{th} and 11^{th} harmonics. 12-Pulse drives are significantly more expensive, and are a source of the 11^{th} and 13^{th} harmonics, but through their design are able to eliminate the 5^{th} and 7^{th}.

In general, harmonics present on a distribution system can have the following deleterious effects:

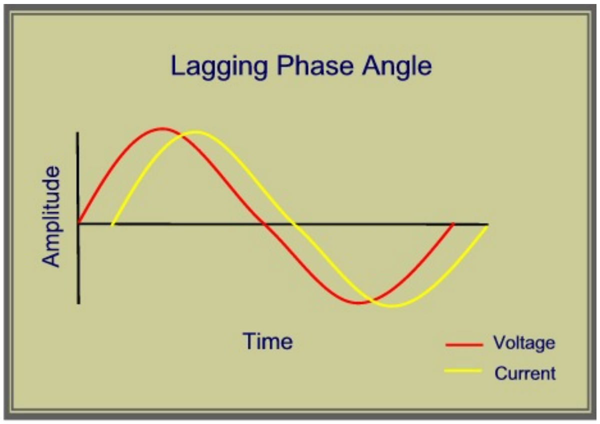
- Overheating of transformers & rotating equipment
- Increased Hysteresis losses
- Decreased kVA capacity
- Neutral overloading
- Unacceptable neutral-to-ground voltages
- Distorted voltage and current waveforms
- Failed capacitor banks
- Breakers and fuses tripping
- Interference on phone and communications systems
- Unreliable operation of electronic equipment
- Erroneous register of electric meters
- Wasted energy / higher electric bills - kW & kWh
- Wasted capacity - Inefficient distribution of power
- Increased maintenance of equipment and machinery

The Hershey Solution: The standard Hershey system will incorporate broadband harmonic filtering to mitigate the effects of harmonics in the system and render them to a harmless level, thereby helping to release kVA capacity in the transformer, while protecting conductors from overheating, improving the operation of plant equipment and reducing the losses caused by the harmonics.

This is accomplished through the application of variable, non-saturable, zig-zag reactors both at the source of the harmonic currents (load) and at the transformer in the mainframe unit. Furthermore, if harmonics of excessive magnitude exist, *optional* specific harmonic filtering can be employed at the customer's request.



Power Factor

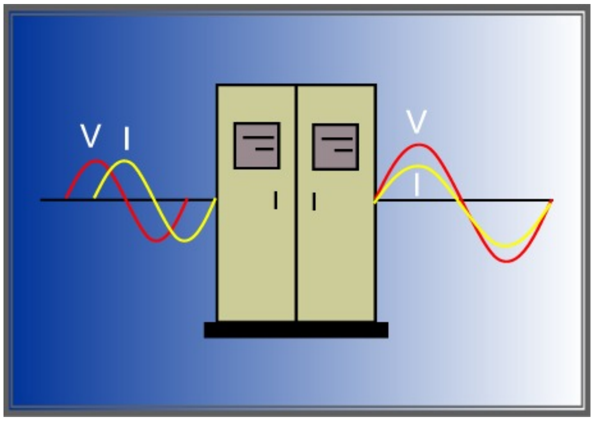


$$PF = \cos\phi = \frac{Real\ Power\ (kW)}{Apparent\ Power\ (kVA)}$$

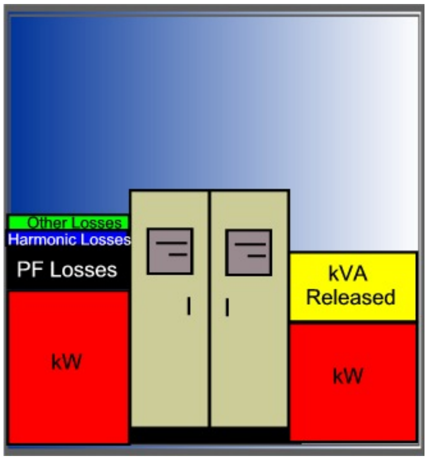
Power Factor: As shown above, Power Factor is the ratio of Real Power (kW) to Apparent Power (kVA). In a purely resistive circuit, all of the current delivered to the load is converted to real work (kW). Therefore, the kW=kVA, and the Power Factor = 1 (unity). However, many loads in industry today are inductive. This inductance causes the current to lag behind the voltage, and the reactive and harmonic currents drawn are used to create the magnetic field needed to operate these machines. Thus, power is lost in the magnetic field and kW < kVA, and the Power Factor < 1. Low Power Factor causes the following adverse effects:

- Increased line losses - I^2R.
- Wasted generation capacity (kVA).
- Wasted distribution / transformer capacity (kVA).
- Wasted system capacity (kVA).
- Reduced system efficiency (kW).
- Increased max. demand (kVA), & related charges.
- Possible poor power factor penalty charges.
- Increased maintenance of equipment and machinery.
- Wasted energy / higher electric bills - KWD & KWH.
- Wasted investment and operating capital.

The Hershey Solution: The Hershey System uses a variable level of capacitance that is load specific to raise the power factor in an electrical network to –95% to 100%. This will effectively eliminate any charges assessed by the local utility for low power factor and will prevent the system from going into capacitance (current leads the voltage) during low load situations. Unlike traditional capacitor banks, the Hershey System also incorporates harmonic filters that will eliminate any resonance in the network. Finally, all Hershey installations employ a self-diagnostic feature that provides an audible alert in the case of a capacitor cell failure. Furthermore, any stage under alarm will be taken off-line.



Overloaded Transformers (loss of kVA capacity)



Overloaded Transformers: Overloaded transformers are found in industry as a result of a combination of factors. Often times rapid plant expansion without adequate capacity planning can lead to overloaded transformers. This combined with the poor power factor and high harmonic currents generated by inductive loads, can cause a transformer to become heavily loaded. Whatever the cause, an overloaded transformer presents an obstacle to future plant expansion and heavily overloaded transformers can overheat and pose a potential fire hazard.

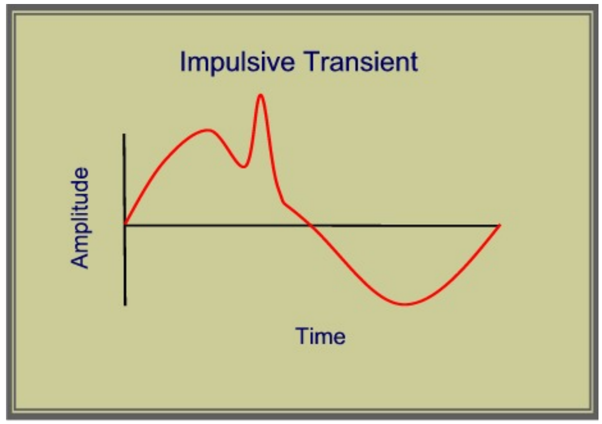
The Hershey Solution: The standard Hershey system will increase the kVA capacity on a given transformer up to 45-50%, depending upon the pre-existing conditions and inefficiencies on that transformer. The releasing of kVA capacity is a by-product of the standard features of the Hershey System.

This will allow for additional expansion on the given electrical network and avoid costly transformer upgrades. It is accomplished by reducing the following:

- Power factor losses
- Harmonic losses
- Negative voltage sequence losses
- Circulating current losses
- Hysteresis

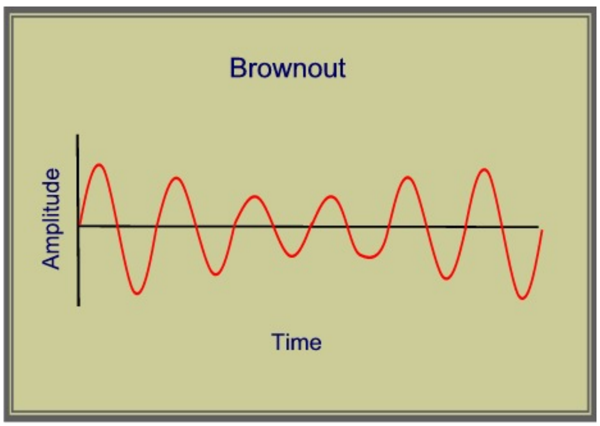
Lightning

Lightning: Lightning can cause serious problems and extensive damage in an electrical distribution system. As mentioned previously, lightning strikes can cause intermittent supply failures. In fact, EPRI has estimated that lightning causes approximately 30% of all power outages. In addition, lightning can generate dangerously high-magnitude transient overvoltages that flow into a distribution system.



The Hershey Solution: The standard Hershey system will provide a dual layer of protection from lightning generated transients. As mentioned previously, the Hershey System uses a lower impedance value to trap an infinite number of transients and swells thus protecting plant equipment. Furthermore, all units in the Hershey System are installed with lightning arresters. Finally, the Hershey System can be designed with the *optional* 1-second carry through to provide 59/60 cycles of ride-through power.

Brownouts



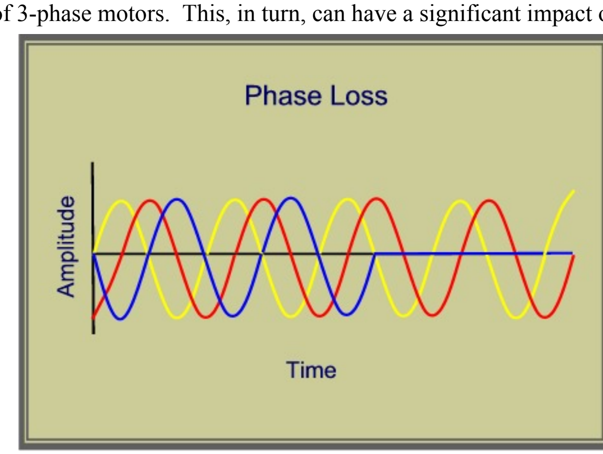
Brownouts: Although no formal definition exists in the power quality literature, the term "brownout" is generally used to describe a long-duration undervoltage condition. These long-duration undervoltage conditions can cause the following problems in a distribution system:

- Equipment shutdowns
- Loss of microprocessor memory
- Reduced motor torque, increased stalling
- Overheating of motors (insulation breakdown).
- Tripping of protective devices
- Speed variation in ASDs

The Hershey Solution: Brownout Protection is an *optional* feature of the Hershey System that will provide for real time voltage improvement and stability to compensate for the undervoltage conditions experienced during electrical brownouts.

Electrical Phase Losses

Electrical Phase Losses: The loss of a phase can have serious consequences for a manufacturing operation. Dropping a phase can result in insulation breakdown and lead quickly to the destruction of 3-phase motors. This, in turn, can have a significant impact on production schedules creating wasted product and downtime. Both of these factors combined represent a significant loss of capital to a company.



The Hershey Solution: Phase Loss Synthesis is the fourth and final *optional* feature of the Hershey System. The Hershey System is able to detect the lost phase, and utilizing inductance, capacitance and close-tolerance resistors, can create the lost phase from the remaining two. This can be accomplished indefinitely until the lost phase is restored. It should be noted that this option supports a maximum of 67% of the full load amperage on the distribution system. Therefore, load shedding will be required before the system will engage. Furthermore, this option requires a special design with specific criteria that must be met prior to design and implementation (ex. Ampacity of the conductors must be sufficient to carry the load of the remaining 2 phases etc.)

For more information on the Hershey Power Conditioning System, visit www.hersheyenergy.com.

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