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# The USES Unit and the Electrical System of a Cold Storage Plant

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Electrical power is used extensively in cold storage plants in refrigeration compressors, fans, lighting, fork lifts, conveyor belts and office equipment. It is important to maximize the power factor in this inductive electrical environment so that electrical power is utilized efficiently and the reactive power returned to the utility is minimized. Toward this goal, the USES unit recently was introduced. USES units can be used in conjunction with existing power factor correction capacitors to raise the power factor of individual motors or panels and of the entire plant incrementally toward unity.

The USES unit provides a new combination of benefits. In addition to correcting the power factor, the USES unit:

- ▼ balances amperage and voltage across phases, which smooths out motor operation;
- ▼ makes reactive power useful to the load;
- ▼ reduces total harmonic current content;
- ▼ reduces line transmitted and motor generated noise;
- ▼ suppresses voltage surges and spikes;
- ▼ improves voltage regulation;
- ▼ reduces wattage;
- ▼ reduces current on the line and on the neutral; and
- ▼ reduces magnetic fields.

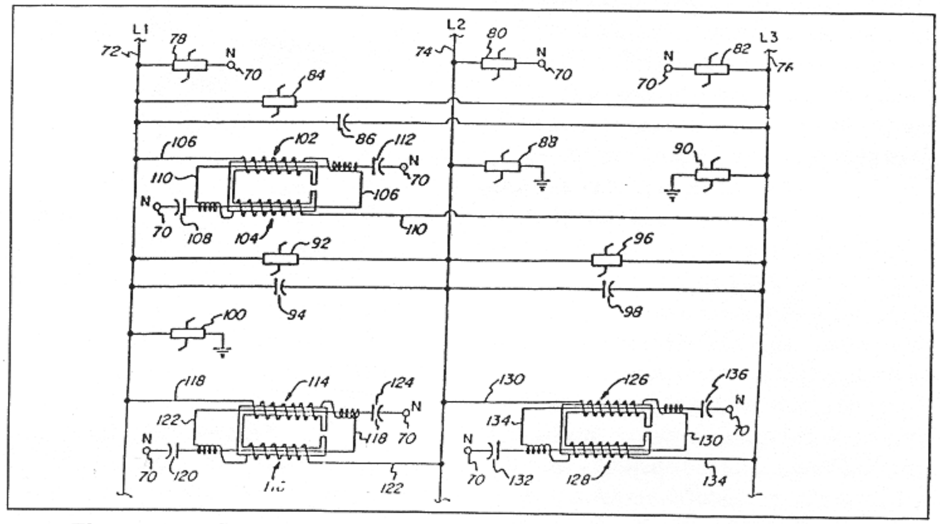


***Figure 1 — General Schematic Diagram of Magnetic Choke Circuit***

The material in this report describes the general USES effect and then gives specific results that have been obtained through the study and use of these power conditioning units.

## USES Effect

In general, most losses and inefficiencies in electrical systems are associated with magnetism. Examples of magnetism include:

- ▼ induction motors;
- ▼ HID lighting ballasts;
- ▼ rectifiers in DC current conversion;
- ▼ transformers in power conditioning and surge suppression devices; and
- ▼ the step down transformers that supply the power to the loads.

If losses due to magnetic effects can be minimized, more efficient electrical systems result. The USES circuit comprises a method for monitoring the magnetic forces within an electrical system and then provides an electric signal that minimizes these inefficiencies.

The means through which the USES circuit, embodied in the USES Shunt Efficiency System (USES), implements this concept is through a system of parallel, wrap-around magnetic chokes. The chokes are oriented to efficiently couple the magnetic forces generated by the current flowing in each electrical phase. On the basis of the magnetic field sensed, an electric signal is generated that compensates for the effect of this field. Also, the AC waveform is enhanced and adjusted to meet more closely the requirements of inductive loads in the system. Furthermore, the peak portion of the current waveform is decreased on the line side of the USES connection point, requiring less output of the supplying transformer.

A 3-phase USES circuit (Figure 1) consists of a system of parallel, wrap-around magnetic chokes. The chokes are oriented to couple magnetic forces generated by the current flowing in each electrical phase. The operation of the chokes tends to align current and voltage waveforms, thus correcting the power factor and reducing current demand. The USES circuit balances phase amperages, which smooths out the operation of motors. The USES circuit reprocesses excess electric energy, making it a component of useful energy. The magnetic chokes absorb repeated voltage spikes, thereby protecting system components from electrical damage.

An important phenomenon associated with the operation of the magnetic chokes in triphasic systems is that, because of the magnetic coupling between phases, the phase amperages and voltages become more closely balanced. This interphasic balance, in addition to reducing the current on the neutral in the wye system and reducing harmonic current, has profoundly beneficial effects on the operation of inductive motors. Inductive motors are widely used in refrigeration equipment. Inductive motors use a rotating magnetic field as a means of driving an armature not provided with commutator and brushes in the manner previously taken as a matter of course. Instead, the working current is developed in a closed winding by induction. In the triphasic motor, the field windings, which are arranged 120° apart, induce a rotating magnetic field which may be resolved into two components, each varying harmonically in time but stationary in space, and differing from each other, both in time and space, by 120 electrical degrees. For the original description, see U.S. Patent #382, 280 by Nicola Tesla, assigned to Westinghouse Electrical and Manufacturing Co. in 1886.

In this rotating magnetic field (Figure 2), maximum efficiency of the motor is achieved if the magnetic flux envelope is radically symmetrical with respect to the armature. If the three phase currents feeding the field windings are unbalanced, then the resultant asymmetric magnetic field gives rise to retarding m. m. f. and results in reduction of available horsepower. This imbalance also causes eddy currents and harmonic currents in the field windings and the armature, resulting in heat, electrical noise and mechanical vibration, all of which degrade the motor physically and dynamically.

When the USES unit is connected in parallel with the inductive motor, the motor operation noticeably "smooths out" because of the considerations described earlier. However, an additional advantage also is achieved. By means of the magnetic coupling between phases through the magnetic chokes, the reactive component of the power, a resultant inefficiency of the field windings, is not returned to the utility, but is made available to the load. Thus, the power commuted between phases is true power and raises the power factor of the motor and the entire plant.

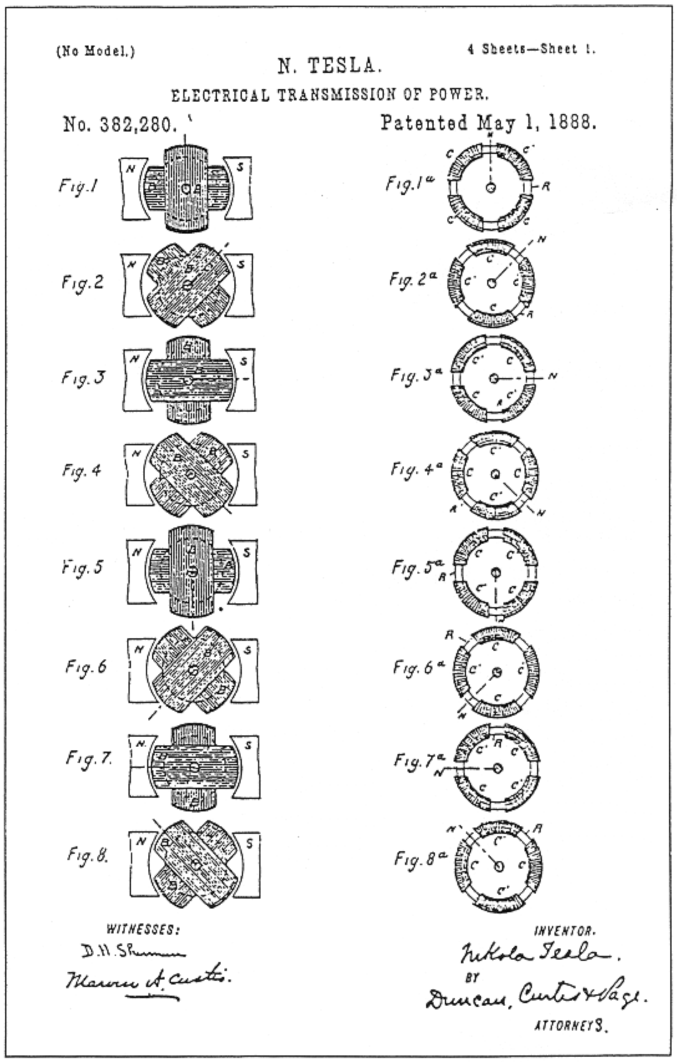


*Figure 2 — The Rotating Magnetic Field*

## How USES Supports Greater Efficiency in Electrical Systems

The USES process, when implemented, has far reaching effects in any AC electrical system. Underwriters Laboratory (UL) evaluated the USES unit and summarized the benefits.

### Reduces Total Harmonic Count

**Explanation:** Variance of an AC waveform from a sine wave affects the magnetic field monitored by the magnetic choke. Accordingly, the USES process reduces not only harmonic current content, but related, distorting effects on the voltage waveform. Predominant sources of current harmonics and voltage waveform distortion are non-linear, switching loads such as computers, variable frequency motor controls and digital processors. The presence of these type loads in the electric system creates aberrations which affect other electrical/electronic loads. In cold storage plants, the use of equipment that produces harmonics makes it essential to reduce harmonic current and to restore distorted voltage waveforms so that the operation of the compressor motors will not be degraded.

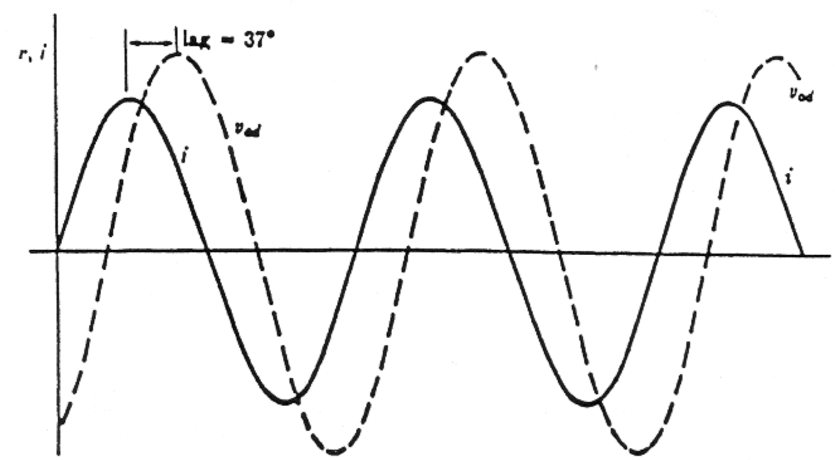


*Figure 3 — Corrects Power Factor*

## Suppresses Voltage Surges and Spikes

**Explanation:** In the USES circuit, the magnetic chokes provide surge/spike suppression. For these electrical transients, the magnetic chokes act like sponges, drawing excess energy off the line before it can cause harmful effects. The excess energy is temporarily stored and returned to the system as additional useful power. Since the process can be repeated over and over, the basic surge protection capability of the magnetic choke system absorbs an unlimited number of transients. This is termed "inherent self-healing capability."

Furthermore, the transients are transmuted continously by the USES unit into useful power. This enables the unit to handle surges indefinitely without becoming saturated or burned out. Amplitudes of absorbed surges often are below the clamping cutoffs of other surge suppression devices. Although unnoticeable to the user, after many repetitions, small transients induce real damage, shortening the useful life of system components.

## Corrects Power Factor

**Explanation:** The power commuted between phases through the wrap-around magnetic chokes is independent of the phase relation between the amperage and voltage waveforms. In the process of balancing the power between the phases, the voltage and current on the line side of the USES unit come into phase (i.e., the power factor becomes closer to unity). Figure 3 shows the current lagging the voltage by 37°, which corresponds to a power factor of .80 and is characteristic of inductive motor loads. The standard method of correcting this lagging current has been to connect a large capacitor in parallel to the motor. This use of large capacitors, however, is not without cost in system efficiency.

The capacitors, which are either added in a bank at the service entrance or individually in parallel with inductive loads, are in themselves inefficient loads. Capacitors heat up from I*I*Z power losses, particularly when they are being driven at high power levels. Also, there is no convenient way to tell whether they are still functioning and those containing inflammable fluids have been known to explode, causing injury and system down time. Capacitors are of fixed rating and do not accommodate variable load conditions unless more expensive variable capacitors are used.

Large capacitors used throughout the system cause harmonics due to R/C/L resonance, causing voltage fluctuations. On Navy ships, large capacitors are used sparingly because the R/C/L resonance causes migrating voltage "hot spots" which are difficult to predict or control and may cause explosions, accidents and equipment failures.

Correcting power factor toward unity in an electrical system reduces current drawn on the line, resulting in a savings in electrical energy due to a reduction of $I^2Z$ losses all the way back to the point of energy generation. In cold storage plants, this savings becomes significant, particularly in compressor motors, lighting and ventilation where the inductive loads are remote from the transformers. Plant power factor correction also results in a reduced penalty on the electric bill.

Note: Z is the impedance of the ac circuit which is derived from the ohmic resistance and the inductive and capacitive reactances. Impedence power loss in an ac circuit is analogous to resistive power loss in a dc circuit. In electronic circuits in which inductive and capacitive reactances are used in the design of amplifiers, the term"impedance matching" is used to describe the process of maximizing amplification. Similarly, in a 60 HZ electrical system that has harmonics, the USES Units perform instantaneous and continuous impedance matching to achieve maximum efficiency for the entire system.

## Improves Voltage Regulation

**Explanation:** The inherent properties of the magnetic choke operation produce a natural tendency to hold voltage steady during momentary voltage fluctuations on the line. In an electrical system, a voltage spike in the upward direction induces a current spike in the negative direction, which induces magnetic field variations leading to eddy currents. Therefore, the system tends to overcompensate for the original spike. Conversely, downward spikes occur when equipment is started, causing a draw down the line voltage met by an overcompensating upward spike in the current.

Both over-voltage and under-voltage have a deleterious effect on the electrical and electronic systems components, but for different reasons. Conditions of over-voltage, i.e., higher-than-design potential energy, can cause breakdowns in insulation, allowing current flow between phases, neutral or ground; shorting electrical components; breaking down semiconductors; creating avalanche currents; and overheating junctions. Less intuitive are the effects of under voltage. Electrical components tend to operate at design power consumption. Since power consumption is directly related to the product of voltage and current, when voltage decreases, current must increase. Higher-than-design currents caused by lower than design voltage results in overheating conductors within the electrical/electron components. This overheating causes insulation breakdown and electrical shorts and reduces equipment lifetime.

Near a USES circuit, voltage regulation is improved for upward voltage shifts by action of the magnetic choke and capacitor circuit. The USES unit is not classified as a voltage regulator. Nevertheless, for reasons described earlier, voltage regulation and responsiveness to momentary fluctuations will be improved with the installation of a USES unit. In cold storage plants where the product and equipment must be protected, equipment failure will be reduced.

## Help Reduce Wattage

**Explanation:** The unique design of the parallel, wrap-around magnetic choke results in a savings of true power in an inductively loaded system. This savings is generated by the shunting of normally wasted energy from one phase to another and is achieved over and above that which might be due to power factor correction. A detailed explanation of the process is proprietary and beyond the scope of this report. The precise sizing and placement of USES units greatly affect the savings and require analysis of a particular electrical system. This is a service provided by Pure Power Systems, Inc. In cold storage plants, the reduction of wattage and current reduces interferences within the system and saves on power bills.

## Field Experience with USES Units in Cold Storage Plants

Between October 1993 and July 1994, the Coldwater Seafood Corporation of Cambridge, Md., installed 11 480 V, three-phase USES units parallel to the main compressor motors in the north end of its plant.

On Saturday, November 26, 1994, an electrical plant accident occurred at the Coldwater Plant. Sifting through the evidence, they believe there was a major voltage sag. Although the voltage sag lasted only a few seconds, it caused the plant considerable electrical damage, knocking out two of the three single phase transformers that supply electricity to the south end weekend loads. The phase protection on that set of transformers, designed to protect against single phasing, never tripped — its magnetic coil melted. Two of the transformers were knocked out. Next, single phasing did occur and caused several motors to burn out. On that circuit, coils in the 480 V and 110 V motor starters were melted and the contacts were welded together.

No damage was sustained in the north end of the plant, even though the 12 transformers located on the roof of Coldwater Seafood were wired in parallel. The north end contains the main compressor motors and typically draws 10 to 20 times the amount of power as the south end during a weekend.

According to a news release prepared at Coldwater, "All those north end loads had been protected by USES units, which evidently do stabilize voltage as claimed. These units not only saved the large motors from damage, preventing a loss of temperature in the freezers, but they protected the upline transformers. The investment in the USES units certainly has been repaid, particularly since they also have dropped the kW demand in the north end by 30 to 40 kW."

USES units are manufactured by USES Manufacturing, Inc., in Quaker Hill, Conn. and installed by Pure Power Systems, Inc. ■

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