Powerhouse
White Paper
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When installed at a **Main Distribution Panel (MDP)**, the ***Powerhouse*** levels, boosts, and maintains voltage on all phases, no matter the load, of a wye system that uses a neutral. Below are definitions of some terms which are utilized throughout this paper:

- **Inductive Load** - any load requiring a magnetic field to operate (motors, inductive capacitors, gaseous tube lighting ballasts, transformers, inductive furnaces, fans, relays, solenoids and chillers). Inductive loads draw a large amount of current (inrush current) when first energized, then decrease after a few cycles to a full-load running current.
- **Non-Inductive Load (Resistive Load)** - any load not containing capacitance or induction such as incandescent lighting or electrical heaters, ovens, burners and toasters. The current instantly attains its steady-state level without first rising to a higher level.
- **Reactive Power** - the power required to start and maintain a magnetic field in an inductive load. Although reactive power is necessary in operation, it does not provide real work **(kW)** and is eventually passed through the neutral line to ground. This is measured in kilovolt-amperes-reactive **(kVAr).**
- **Real Power (kW)** - the actual work an inductive and resistive load performs, as opposed to **kVAr** which does not perform actual work. Utilities bill by the **kW** and sometimes penalize on the amount of **kVAr**.
- **Apparent Power (kVA)** - measured in kilovolt-amperes, is the sum of **kW + kVAr.** It is the total power supplied to an **MDP**.
- **Power Factor** - a ratio of real power **(kW)** and apparent power **(kVA)**: **kW/kVA.** This is a measure of efficiency. The highest power factor desired is 100% or 1. A number less than 1 indicates inefficiencies within the load. A power factor of 0.80, or 80%, indicates an inefficiency of 20%. Inductive loads lead to a much lower power factor because of the non-working power needed to maintain their magnetic fields. Non-inductive or resistive loads approach 100% efficiency.

Problem: Power, as supplied by the utilities, can be fraught with issues even before the consumer is able utilize it. These can include blackouts, brownouts, line harmonics due to electromagnetic pulses (EMPs), and issues due to sudden spikes in upline or downline use. Inside the facilities, power surges, spikes and sags create undue disruption and wear on any motors, chillers, lights, and electrical devices (computers, TVs, outlets, UPS equipment, digital displays, rectifiers, relays, breakers, switches, monitors, etc). Temporary disruptions (brownouts) or more long term outages (blackouts) don't necessarily cause problems or damage when the system is down or off but most likely creates a spike as well as sags when suddenly energized or turned on. This alone is the greatest cause of equipment failure.

Low power factor creates more heat for the inductive load because more current (heat) is needed to make up for the inefficiencies of the load. Even though the damage can occur over a longer period of time, excessive heat, in the form of current, is detrimental and destructive to motors. Higher power factor will help with efficiency and increase the longevity of motors by reducing the heat (current) greatly.

Harmonics occur when voltage and current are not in phase with one another with their respective sine waves. Measured as total harmonic distortion (THD), harmonics are merely a byproduct of a nonlinear load. Examples of nonlinear loads are battery chargers, adaptors, fluorescent lamps (because of the choke coil), LEDs, electronic ballasts, variable frequency drives (VFDs), rectifiers, uninterruptible power supply (UPS), switching mode power supplies (SMPS), photocopiers, personal computers, laser printers and fax machines. However, in a linear load, both voltage and current follow one another without distortion to their pure sine waves. Examples of linear loads are resistive heaters, incandescent lamps, and constant speed induction and synchronous motors.

Effects: The consumer ultimately pays the price in many ways:

1. Most utilities penalize commercial users who operate with low power factor (usually under 0.9) in the form of demand charges. If it is not labeled as such on a power bill, this may be disguised as a "fee".
2. Maintenance cost of equipment can account for a company's greatest expense. Reduction of heat (current) and higher efficiency (power factor) can reduce or significantly defer maintenance costs.
3. Most power systems can accommodate a certain level of harmonic currents but will experience problems when harmonics become a significant component of the overall load. As these higher frequency harmonic currents flow through the power system, they can cause a plethora of problems, including:

- communication errors
- overheating and damage to hardware
- overheating of electrical distribution equipment (cables, transformers, standby generators, etc.)
- high voltages and circulating currents caused by harmonic resonance
- equipment malfunctions due to excessive voltage distortion

- increased internal energy losses in connected equipment causing component failure and shortened life span
- false tripping of circuit breakers
- metering errors
- fires in wiring and distribution systems
- generator failures
- lower system power factor, resulting in penalties on monthly utility bills.

Solution: The ***Powerhouse*** addresses these issues through its use of certain components working in concert to capture and recycle reactive power (kVAr) for its reuse. Its unique wiring configuration (***Patent #US8971007***) allows these components to redirect the kVAr to either a capacitive or distributive function as needed within a facility's power grid. An array of 18 metal oxide varistors (MOVs), each rated at 100 kA, act as surge arresters through a series of internal diodes and resistors. There are six MOVs connected in parallel to each phase for a total of 600 kA rating per phase. The ***Powerhouse's*** patented wiring configuration allows the MOVs to redirect the many spikes in voltage a facility experiences on a daily basis to a series of fluid-filled capacitors for eventual distribution in the case of a sag or dip in voltage, which usually occurs during sudden upsurges in power consumption within a facility. Additionally, the wiring configuration allows for the neutral (which is designed to carry a load) to be utilized as a secondary power source and is connected inside the ***Powerhouse*** so that it can be redirected in a capacitive or distributive function. In this way, the ***Powerhouse*** treats the neutral as a "phase D" within a three phase system. It is for this reason alone that the ***Powerhouse*** can only operate within a wye and not a delta system, since the delta does not use a neutral. Also, a delta system generally has a "high leg", making it impractical if not impossible to balance voltage between the phases. The constant and consistent "back and forth" between the MOVs and the capacitors keeps the voltage between the phases boosted, leveled and maintained at all times no matter the load -- sudden or otherwise -- within a facility's grid. Similarly, the ***Powerhouse*** protects against spikes or surges when the grid is suddenly energized after a power brownout or blackout. For added protection, a secondary surge protector within the ***Powerhouse*** protects the grid for up to 50,000 volts.

When the neutral is utilized within the ***Powerhouse***, a unique effect occurs. All values for kW, kWh, kVA, Amperes and kVAr are lowered in a pronounced way. Conversely, power factor increases to typically between 0.99 and 1.0, and voltage increases and levels in all phases. These effects are confirmed by repeated on/off power logger data tests, and in various independent studies of the ***Powerhouse*** performed by General Electric, Applied Research Laboratories, the Department of Defense and the Department of Energy.

What sets the ***Powerhouse*** apart from all other manufacturers of power factor correction equipment is this meaningful drop in kW or kWh. Equipment and lighting within a facility still operate at the kW that they are rated for (as inductive and resistive loads are always going to run true to their rated kWs). The ***Powerhouse's*** ability to recycle the kVAr slows the kVA draw from the supply side (utility). This causes the appearance of a kW drop within the facility which will be reflected on the consumer's power bill. This is the "exception to the rule" when it comes to power correction equipment.
The ***Powerhouse*** also eliminates about 80% of the harmonics, which is usually the greatest concern of energy managers and electrical engineers of any facility. The increasing use of VFDs and UPSs in facilities leads to the increasing need to address problems associated with harmonics. The ***Powerhouse*** solves these issues.

Summary: In order to determine the health of a facility's power grid, power data loggers are necessary to get an overall picture (typically 24 hours) of a facility's habits in power usage as well as all the values related to that use. Based upon those values, a capacitor bank is carefully calculated for the proper size to ensure adequate return of kVAr as fed to the capacitors by the neutral and MOVs. It is preferable that a switchable capacitor bank is utilized for maximum efficiency at all times, as it will vary the capacitance (as much as 1700 kVAr) as the load dictates. Voltage between the phases are balanced, boosted, leveled and maintained at all times. Power factor is corrected to an ideal .99 -1.0 and will result in the reduction in demand charges and the elimination of the associated penalties. KW is decreased enough to significantly lower power bills, since utilities generally charge by the kW or kWh. Induction loads run up to 30-40% cooler and operate more efficiently. Harmonics are mostly eliminated and will no longer pose a problem to a facility.

Currently, all of the components of the ***Powerhouse*** as well as the switchable capacitor banks are manufactured and assembled in General Electric's, Clearwater, FL plant. With over 600 units installed and more being installed daily, the ***Powerhouse*** is proving itself in a wide variety of settings: restaurants, resorts, hotels and convention centers, mines, lumber mills, industrial processing plants, grocery stores, colleges and school systems. The Department of Defense and the Department of Energy has completed testing of the ***Powerhouse*** and has accepted its technology, so far, as a "sole source product" for their military bases. The ***Powerhouse*** is truly a "one device fits all" for all power conditions.