# Protecting the Power Grid and Its Customers
# From Solar Flares and EMP Attacks plus adding Reliability and Energy Savings

When considering issues involving the power grid, the causes of power outages, and the effect of outages on power substations, power distribution, and customers, it seems that the information presented is correct, but often misunderstood. There is more of this on how to prevent damage and helping to keep customers (people) alive during and after an "event" should the event be a solar flare or an electro-magnetic pulse bomb caused by an enemy attack.

Many news stories, articles and broadcasts try to focus on how to survive after an event; however, most of the solutions described "advocate the use capacitors", SPDs or surge arrestors, and Faraday cages to allow the power grid and a few important buildings to survive the event. It seems there are many scare tactics used to try to force people into wrongly believing they may have a chance of survival if they support these claims and proposed solutions.

**None of these proposed solutions help the customers (people) survive, nor do they protect sensitive electrical equipment long enough to be of value. Even the survivors will not have operational electrical equipment after power is restored in the 6-to-24 months estimated by many "experts".**

There is a complete lack of understanding when it comes to protecting the grid or the customers in the event of either of the above events.

**Capacitors** are thin conductors separated by even thinner layers of insulation. Capacitors have a design rating for current and voltage. If this rating is not exceeded they will typically operate for 10 to 15 years. One high voltage spike may (and generally will) cause catastrophic failure of capacitors. In factories with 4,000 power factor correction capacitors, it is not uncommon to have 300 to 500 capacitors fail each year due to high harmonic current or high voltage spikes.

**Capacitors cannot protect the power grid or the general public.**

**SPD (Surge Protective Devices**) are solid state devices constructed in various sizes. Like capacitors, their ratings are also in current and voltage. When the MOV (metal oxide varistor) is hit with many low-level voltage spikes it degrades, and the "clamping voltage" will rise as the MOV breaks down, allowing the clamping voltage to continue to rise until it no longer protects the equipment it was installed to protect. When a voltage spike hits the MOV above the rated voltage, it starts to conduct thousands of amps to ground, causing noise on the ground system and very high heat within the SPD. If the event is longer than a few millionths of a second, the MOV could be destroyed, and therefore would no longer protect the equipment it was installed to protect. The recent event in Canada lasted over 90 seconds.

**SPDs cannot protect the power grid or the general public.**

**Faraday cages** have been used for many years to house and protect computer hardware and sensitive data in factories, as well as some government and military buildings. They recently have been touted as a solution to solar flares, lightning and EMP pulse issues. However, most buildings are not built within a metal enclosure and it is difficult and expensive to properly design and build these enclosures. Most automobiles, trucks, trains and planes are totally enclosed by metal, but they offer no protection from any of these events. By design, the metal enclosure must have a suitable solid ground connection as it relies heavily on enclosing and shielding the sensitive electrical equipment and removing the energy by draining it to ground. The power company uses the Faraday cage design in some of their grid tie substations. They are extremely large and expensive. The cost is approximately $250,000,000 to tie two (2) 138,000 volt portions of the power grid.

During a serious event the cars will stop, the trains and trucks will stop and the planes will simply fall from the sky. No, enclosing the equipment in a metal enclosure does not shield or protect it from these events. Many experts expect everyone with a pace maker to be dead from events of this magnitude. People cannot walk around wearing a protective cage or drive while connected solidly to ground.

**Faraday cages cannot protect the power grid or the general public.**

Products utilizing these methods are available from the same company who sold the smart grid technology which replaced the operators (people) with computers and other solid state controls (not people). Now they are recommending their products to send the noise and unwanted energy to ground to protect the grid.

Well, what do we do when the ground is full? Most experts believe the earth is the ultimate zero reference for voltage. This is not true. The detection testing for the geomagnetic storms and other phenomenon is detected when burying conductors over three feet underground and over three hundred feet apart. Then the voltage difference is measured. If the earth was a zero reference for voltage there would not be a difference and all the tests would fail. When metal rods are driven into the ground at a consistent spacing a difference of voltage is always present. This is called an earth battery.

In many industrial facilities, there is an attempt to follow all the rules from the National Electric Code, IEEE, ANSI and IEC standards, as well to properly ground the power components in order to clean up the power for trouble-free operation. When staticallyshielded isolation transformers are employed with grounded wye power transformers and shielded control transformers with the shield and the X2 side of the transformer grounded, the grounds from all these sources of noise connect to a common terminal block per the standards, and one ground wire is run and connected or bonded to the power system's ground mat. All the noise from the static shields and the Neutral point of the grounded wye transformer and the X2 side of the control transformer all share all the noise that they are expecting to remove by using this typical method of grounding. The results are generally poor at best, with continuous control anomalies even when a UPS is installed to power the controls.

Another example of the earth not being a zero voltage reference: when lightning strikes a tree, the current flows to ground from the tree to the root system into the ground and comes back up everyone's ground rods, destroying wired phone systems, sensitive appliances, well pumps and their controls, and even larger appliances including washers, dryers and refrigerators. Compact fluorescent light bulbs are destroyed even with the lights switched off. This happens even when the residents live hundreds of feet apart. Farmers have lost animals caused by the difference of voltage between their feet. Even large farm animals including fully grown cows are killed by this.

No, the earth is not a zero voltage reference during these events. Being connected or bonded to ground does not assure that you or your equipment will survive. Many facilities with a solidly and properly grounded power system have the highest amount of short circuit current available during an arc-flash event. The more solid the ground, the worse it can be for the people to service this equipment from a safety standpoint.

There are many papers, articles and news broadcasts by experts indicating that this is the best we can do. They indicate with much fervor what life will be like after the inevitable event, and argue amongst themselves whose picture or vision of the solution is more accurate. However, none of these proposed solutions will keep the populace alive and protected. The predictions of many deaths are a certainty when none of the mentioned plans will protect the general public's power systems and electrical devices or the grid for that matter. The present recovery plans include many replacement parts which will require 6 to 24 months to repair or re place. Everyone in the Northern part of the country will not survive a winter waiting for the power to come back and then waiting for fuel for their furnace and cooking. Where are the replacements for the damaged power transformers and control systems to repair the power grid and computers in all the vehicles we rely on to supply the grocery stores, transport people/survivors to the hospital and transport fuel to the gas stations? Yes, many will not survive during the time it takes while electrical workers and their vehicles and cranes operate to repair the damaged grid components after responding to the event.

There is a general gloom and doom message predicting the starvation of millions of people, unless everyone supports their very narrow vision of a solution, which they estimate will cost 2 to 20 billion dollars to fix, and they have an escape clause stating that it may already be too late.

With all this in mind: Solid State components are damaged and destroyed by catastrophic global solar flares, and local events like lightning and EMP pulses and capacitors are damaged and destroyed by high voltage spikes like the ones during lightning storms, and Faraday cages will not prevent current from traveling through ground and back into the power grid or be used by over 300 million people in the United States, so what can we do?

There is only one known patented solution to solve the problems caused by high energy issues including lightning, EMP pulse and solar flares, and all other sources of electrical disturbances and noise issues because it operates at the speed of current flow the same as the event that would be responsible for the damage. It has been proven in virtually every sector and industry in the country including residential. The device is called Phaseback VSGR (voltage stabilizing ground reference). It is available in every voltage class from 5 volts DC through even the highest three-phase voltages of the power generation, distribution and the nationwide power grid. It is simply a matter of scale. Every piece of electrical equipment from power generation to every house in the United States and everything in between can be protected. The solution is the same for trains, ships and planes as well as communications to keep the public informed.

In a typical lightning strike or EMP event with a direct hit on the power lines, there will be less than 50,000 volts entering a building, as the transformers can only couple so much power. The 600 volt class Phaseback VSGR has been tested to withstand 200,000 volts being hit continuously for over 30 hours while preventing damage to the power source, the distribution system and all loads connected. Each Phaseback VSGR simply connects in parallel with the loads powered from the transformer secondary.

If or when the power goes down, Phaseback VSGR causes a controlled shutdown and gives the electrical equipment continuous protection. When the power is restored all the equipment can simply be restarted.

Procuring and protecting replacement power transformers and their associated support equipment is a good first step as it will take a long time to fully harden and protect the entire power grid but prevention is the best suppression to solve to this problem.

## Phaseback and the Power Grid

- Protect the Grid
- Increase Kilowatt Hours with no additional Generation by fossil Fuels or Renewables
- Eliminate Substation Switching Transients and the Oscillating Ring Waves they cause
- Extend the Life of Distribution System Capacitors
- Zero Environmental Impact

Phaseback is a voltage stabilizer for power distribution systems that prevents most transient voltage spikes, reduces voltage harmonics and stabilizes the 120 degree phase differential even in ungrounded and open-delta power systems.

According to the Department of Energy, voltage stability and noisy power are (2) two of their major concerns. In fact, the power loss in supplying and distributing electrical power is current squared multiplied by the resistance in the wire. Actually the voltage drop resulting in this effect is added to the voltage drops caused by other losses such as the reactance in the distribution system. Reactance is proportional to frequency so the resulting voltage drop for the third harmonic plus the loss for the fifth harmonic and for the seventh harmonic are all added to the losses for the resistance. If there was a way to lower the current just 5%, the resulting loss just due to the resistance would be 20% less. Reducing the currents due to harmonics and other electrical noise will do exactly that; reduce the losses and increase the amount of fundamental power that can be supplied to customers.

Phaseback has a 12-year track record protecting and cleaning up power systems, making it ideal for wind generators and various other power generating methods. With a Phaseback at each large generator and distribution transformer, the entire distribution system would be simply distributing the generated power to customers with cleaner, more stable power with less power loss. Removing the noise from customer-generated power problems as well as Mother Nature's issues will increase the lifespan of the customers' electrical equipment including electric motors.

Phaseback reduces harmonics by the square law factor. The 3rd harmonic is filtered 9 times, the 5th harmonic is filtered 25 times and the 7th harmonic is filtered 49 times the typical loss of 60Hz noise. This typically reduces all harmonics 50 to 85% from the 2nd harmonic through the 56,000,000th harmonic of 60Hz. Unlike other types of inline filters designed for smoothing the current in 1 or 2 harmonics, Phaseback reduces harmonic noise by beating it against itself so it reduces all harmonics. Phaseback uses no solid state components in the filter circuit, so there is no delay and it starts to correct phase voltage imbalances as small as 100 millivolts at the beginning of the event. The components are inductive and electromagnetic plus pure resistance for removing noise, so clean power can be fed back into the power system. Phaseback does not cause a high current surge to limit phase voltage. The filtering is instantaneous, automatic and reliable.

A power grid, distribution system or facility protected by Phaseback will use less power; electric motors will run cooler and have a longer lifespan. Phaseback provides a predictable positive impact on the bottom line. The design of Phaseback also makes it ideal for low voltage, medium voltage and high voltage systems and applications. Phaseback can also protect the customer's power systems and equipment from serious damage from large electrical problems such as lightning or a possible EMP pulse outside the immediate blast area. The level of damage will be reduced and the recovery time will be much faster. Phaseback can even warn you of the possible presence of an arc-flash hazard.

Phaseback has already survived over 30 hours protecting a power system from 200,000 volt spikes arcing to one lead of a running 3-phase motor without damage and has removed high frequency electrical noise through 3.69 gigahertz. A government paper outlined the effects of lightning and EMP on electrical power systems indicating the voltages at the secondary of the power transformer could reach 50,000 volts and the frequency of the noise is between 10 kHz and 3.5 gigahertz. The standard version of Phaseback already does this.

Phaseback VSGR Scalability
Pat. No. 6,888,709

## Scalability

Written By: William Hinton Director of Engineering
Applied Energy LLC

The scalability of the Phaseback Voltage Stabilizing Ground Reference System (VSGR) is directly proportional to the turn ratio of the transformers used in the system and the KVA of the Power Transformer it is connected to. The function of the VSGR system is based on controlling the system voltage to prevent the problems associated with power anomalies.

The Problem:
Power systems have many electrical issues that affect control and drive system operation in manufacturing facilities and most electrical customers have computers or computerized equipment as well as sensitive audio and video equipment that can be

affected by power system problems. There are billions of dollars lost due to transient overvoltage issues every year even though there are millions of products sold to prevent damage from voltage spikes.

Most power problems are caused by internal events, but the larger problems generally come into the facility from the power feed. Large events can be caused by lightning and potential terrorist attacks on the power grid by use of an EMP pulse bomb. Many inductive loads including motors draw a surge of current to start and cause a spike of voltage when they are turned off. This is common in factories and commercial facilities, but a home owner has the same issues when the well pumps, refrigerator, or air conditioner cycle on and off.

Most electrical power quality products attempt to protect solid state components by using solid state components. This protection scheme does not seem to make sense, as these products have a designated voltage rating that they compare the voltage with, and a delay time to apply a correction as well as a clamping voltage which rises as their solid state components degrade. This results in a shortened lifespan of customer equipment.

Harmonics are also load generated within a facility and they affect most devices with transformers, motors and other inductive loads. Harmonics cause electrical currents at multiples of the fundamental frequency (60 Hz in the USA) which cause additional electrical stress, heat and inefficiency which in turn results in premature equipment failure. For example: if an electrical motor can operate its load while operating 10 degrees cooler, the lifespan of its insulation can be doubled.

Voltage imbalances cause inefficiencies in motor operation and drive faults or damage. For example: a 5% voltage imbalance can cause a 30% current imbalance, reduced torque, added heat and thus operational efficiency is reduced. This leads up to a question: Voltage or Current?

It seems that trying to limit voltage spikes by converting them into current spikes ranging from thousands to hundreds of thousands of amps cannot be efficient. Putting noise on the ground reference all the sensitive loads are connected to cannot prevent noise from entering those loads.

Trying to reduce voltage harmonics with a current smoothing device is generally ineffective as motor drives start and run at lighter loads.

The solution to all these power issues which does not use series connected load carrying inductors or solid state components it is a perfectly energy efficient and an infinitely scalable solution.

The Solution:

Installing one Phaseback VSGR per power transformer addresses and solves these power issues without the negative effects or shortened life of other approaches. Phaseback VSGR connects in parallel with the power system to keep voltages equal, balanced, and free from voltage spikes and arcing ground faults. This causes a reduction in phase voltage harmonics at all frequencies and harmonics of the fundamental frequency, even at extremely high frequencies.

Phasebacks have been successfully incorporated into power systems in hundreds of applications at various voltages with great success as it is a permanent solution.

The VSGR is scalable due to the transformer turns ratio and voltage ratio used on the single-phase transformers used in each Phaseback. For example: The turn ratios range from 2 to one for a 240 volt unit to 17 to one for a 4160 volt Phaseback. This makes Phaseback truly infinitely scalable as single-phase transformers are available in all voltage classes and system voltage ratings. As the system voltage increases, transformers with a higher voltage rating are used which have a higher turns ratio. The filter section of Phaseback is essentially the same in all three-phase Phasebacks. When the system voltage and transformer kVA is known, the proper

Phaseback is simply selected with the input voltage matching the power transformer voltage class, secondary voltages line to line and phase to ground and kVA.

Magnitude and scale are simply a matter of voltage class which dictates enclosure size based on the spacing and clearances; line to line and phase to ground are dictated by various codes and standards and power transformer kVA size. For example: a Phaseback VSGR for a 2,000 kVA 480 volt three-phase system uses a 30"H x 24"W x 12"D enclosure and a Phaseback VSGR for a 12,000 kVA 4,160 volt three-phase system uses a 96"H x 84"W x 60"D enclosure.

The Benefits to this Solution:
The benefits of Phaseback VSGR in the power grid are numerous.

Phaseback does not require customer loads to be interrupted for installation as it connects parallel to the power system and d oes not carry any customer load current.

Phaseback balances and equalizes system voltages phase to ground.

Phaseback protects all loads connected to the power transformer from damage resulting from arcing ground faults, voltage harmonics and voltage spikes even in an ungrounded power system.

Power systems with Phaseback VSGR enjoy safer operation as the incident and magnitude of arc-flash hazard are reduced.

Phaseback provides noise reduction from major events including lightning and EMP events.

Phaseback maintains the ground reference during a power outage panned or not providing an organized shutdown of all equipment . Voltages stabilized in micro grid applications.

Reduces or eliminates issues caused by high impedance leakage to ground causing phase loss faults.

Eliminates voltage spikes and reduces harmonics which are the major causes of capacitor failure. This h as proven to cause extended capacitor life.

Indicates locally and remotely the presence of a ground forming for an early warning of insulation breakdown in the power sys tem.

Efficiency increases of 6% have been reported due to stable and balanced voltages as well as reducing harmonics allowing elec tric motors to run cooler. Additionally, the power system does not need to handle the additional currents caused by harmonics.

Prevention is the best solution.

A Report of an Arc Flash Event that occured

3/16/2012 **ARC FLASH MITIGATION**

Dan,

Here is a quick synopsis of my recent job using Phaseback solutions to restore system balance and provide arc-flash prevention.

The site is a commercial maritime vessel used in the off-shore industry. It is heavily dependent on ungrounded voltage systems for service continuity. You can consider this a true, "No-Break" system, which means these voltage systems MUST tolerate phase grounds without danger to personnel, AND WITHOUT allowing loss of control system authority due to the inherent danger to operating equipment and operating personnel. Two arc-flash events occurred recently while electrical workers were in the process of operating large circuit breakers. In each incident, the same breaker failed explosively, initiating the events. Several workers were injured, one seriously.

A total of four Phaseback units were purchased and installed; two on 690v systems and two on 480v systems. The Principle project electrical engineer (from Europe) enthusiastically endorsed my selection, agreeing that if the unit will stabilize the system voltages, then arc-flash events cannot occur. We proved this by installing one 690v unit, and then forcing a ground on one phase. The grounded phase voltage only dropped 2 volts! At this point, four more Phaseback units were purchased for a second vessel of t he same design.

A large part of this task was to demonstrate to the ship crew that it was now safe to operate the equipment. The demonstration of Phaseback capabilities did this.
During the remainder of this job, Phaseback saved us two additional times. A large, 2.5MVA VSD system twice suffered catastro phic failure and subsequent grounding of a DC link snubber resistor (375kW). When this happened, since the VSD is powered from the 690v system, the DC went to the ship's hull and we believe this was the cause of the earlier arc-flashes. The Phaseback was damaged in these events, but was repaired, and credited with preventing possibly major damage to the equipment and injury to personnel.

Thanks, and you have a great product!

Mike *McClelland*

*MEM* Power Solutions, LLC.

619-602-3374

Source of following Information: [http://www.eia.gov/electricity/annual/](http://www.eia.gov/electricity/annual/)

Electric industry retail statistics by state

| State | Retail sales (million kWh) | Retail revenue (thousand dollars) | Customers |
|---|---|---|---|
| Alabama | 86,183 | 7,910,462 | 2,515,540 |
| Alaska | 6,416 | 1,047,781 | 325,458 |
| Arizona | 75,063 | 7,361,001 | 2,898,628 |
| Arkansas | 46,860 | 3,569,581 | 1,547,905 |
| California | 259,538 | 35,123,306 | 15,010,483 |
| Colorado | 53,685 | 5,042,152 | 2,514,407 |
| Connecticut | 29,492 | 4,584,478 | 1,609,735 |
| Delaware | 11,519 | 1,274,051 | 451,908 |
| District of Columbia | 11,259 | 1,334,657 | 258,099 |
| Florida | 220,674 | 23,028,602 | 9,823,195 |
| Georgia | 130,979 | 12,274,740 | 4,636,424 |
| Hawaii | 9,639 | 3,281,059 | 480,427 |
| Idaho | 23,712 | 1,642,023 | 802,210 |
| Illinois | 143,540 | 12,052,640 | 5,694,834 |

| | | | |
|---|---|---|---|
| Indiana | 105,173 | 8,720,678 | 3,118,574 |
| Iowa | 45,709 | 3,524,261 | 1,563,005 |
| Kansas | 40,293 | 3,761,241 | 1,466,095 |
| Kentucky | 89,048 | 6,462,494 | 2,229,989 |
| Louisiana | 84,731 | 5,844,114 | 2,293,418 |
| Maine | 11,561 | 1,365,674 | 795,598 |
| Maryland | 61,814 | 6,973,713 | 2,468,101 |
| Massachusetts | 55,313 | 7,626,740 | 3,109,560 |
| Michigan | 104,818 | 11,510,089 | 4,784,786 |

Electric industry retail statistics by state

| **State** | **Retail sales (million kWh)** | **Retail revenue (thousand dollars)** | **Customers** |
|---|---|---|---|
| Minnesota | 67,989 | 6,025,263 | 2,606,813 |
| Mississippi | 48,388 | 4,162,529 | 1,490,901 |
| Missouri | 82,435 | 7,029,475 | 3,081,211 |
| Montana | 13,863 | 1,143,421 | 581,831 |
| Nebraska | 30,828 | 2,581,053 | 1,008,147 |
| Nevada | 35,180 | 3,147,509 | 1,240,259 |
| New Hampshire | 10,870 | 1,542,800 | 710,119 |
| New Jersey | 75,053 | 10,266,984 | 3,957,980 |
| New Mexico | 23,179 | 2,046,704 | 1,004,932 |
| New York | 143,163 | 21,683,209 | 8,057,158 |
| North Carolina | 128,085 | 11,720,603 | 4,893,389 |
| North Dakota | 14,717 | 1,151,896 | 410,311 |
| Ohio | 152,457 | 13,907,813 | 5,502,168 |
| Oklahoma | 59,341 | 4,472,291 | 1,965,552 |
| Oregon | 46,689 | 3,834,946 | 1,903,531 |
| Pennsylvania | 144,710 | 14,334,889 | 5,974,108 |
| Rhode Island | 7,708 | 982,109 | 495,200 |
| South Carolina | 77,781 | 7,079,722 | 2,460,297 |
| South Dakota | 11,734 | 996,281 | 450,404 |
| Tennessee | 96,381 | 8,932,734 | 3,189,570 |
| Texas | 365,104 | 31,217,788 | 11,249,644 |
| Utah | 29,723 | 2,331,140 | 1,091,361 |
| Vermont | 5,511 | 783,644 | 360,456 |
| Virginia | 107,795 | 9,779,539 | 3,671,544 |
| Washington | 92,336 | 6,412,022 | 3,236,484 |

| | | | |
|---|---|---|---|
| West Virginia | 30,817 | 2,507,116 | 1,016,833 |
| Wisconsin | 68,820 | 7,077,825 | 2,955,636 |
| Wyoming | 16,971 | 1,220,640 | 329,622 |
| U.S. Total | 3,694,650 | 363,687,480 | 145,293,840 |

“bottom line":
3,694,650,000,000 kwh per year and $363,687,000,000 per year.
2% of 3,694,650,000,000 is 73,893,000,000 kWh reduced per year

| | Total U.S. Electric Power Industry | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Retail Sales (million kWh) | | | Retail Revenue (million dollars) | | | Average Retail Price (cents/kWh) | | |
| Sector | Year 2012 | Year 2011 | Percentage Change | Year 2012 | Year 2011 | Percentage Change | Year 2012 | Year 2011 | Percentage Change |

2% of $363,687,000,000 is $7,273,740,000.00 reduction per year This is a tremendous amount of energy and dollar reduction. Just 2% in energy savings amounts to over 7 billion dollars per year which creates a very attractive **return on investment**. The entire cost of the project implementation could be recovered from the energy savings after which it would be profits to the utility company or create a reduction of cost to consumers.

Potential savings range between 2 and 6 percent

**Sales, Revenue, and Average Retail Price for January through December**

You can get specific information and watch the videos of the tests at **www.Phaseback.com** and Phaseback can be purchased from 540 Grid Solutions LLC, Applied Energy's Distributor with or without an act of congress.

One additional note:

---

Disconnecting from the Utility Grid and setting up independent Microgrids will not provide protection from Solar Flares and EMP attacks.

Twelve Years of solution at the Low Voltage Level

**Observations: Control and Drive Lockup**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 1,374,515 | 1,422,801 | -3.4% | 163,280 | 166,714 | -2.1% | 11.88 | 11.72 | 1.4% |
| Commercial | 1,327,101 | 1,328,057 | -0.1% | 133,898 | 135,926 | -1.5% | 10.09 | 10.23 | -1.4% |
| Industrial | 985,714 | 991,316 | -0.6% | 65,761 | 67,606 | -2.7% | 6.67 | 6.82 | -2.2% |
| Transportation | 7,320 | 7,672 | -4.6% | 747 | 803 | -6.9% | 10.21 | 10.46 | -2.4% |
| All Sectors | 3,694,650 | 3,749,846 | -1.5% | 363,687 | 371,049 | -2.0% | 9.84 | 9.90 | |

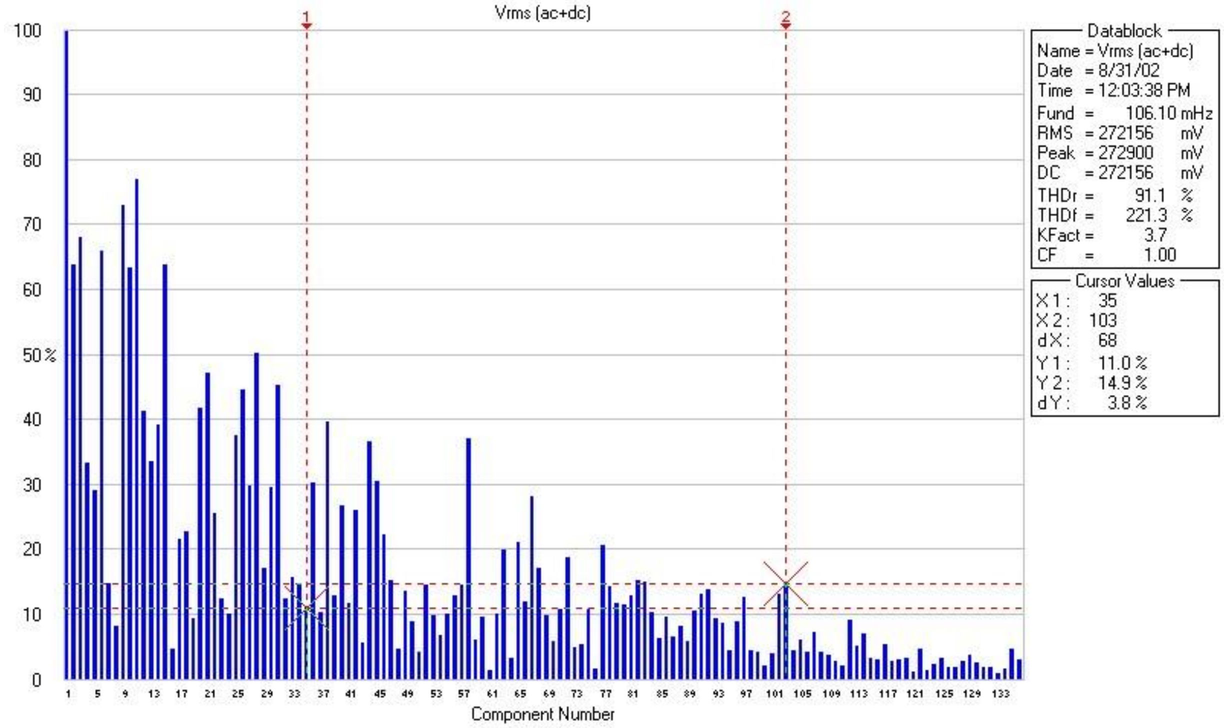
The facility has a 3-phase 3-wire 480 volt "ungrounded" DELTA power distribution system with a 13,800 volt DELTA primary as well. This type of "ungrounded" system also was designed to allow traditional production machinery to continue to operate even with one phase grounded. Herein lies the problem. Adjustable speed drives and control systems are designed to operate with a balanced phase to phase voltage of 480 volts plus or minus 10% with a phase to ground imbalance not exceeding 10%. The power supplies test for a phase loss by testing voltage phase to ground and if this voltage imbalance exceeds 10%, the power supply contactor will not close and it will not supply the DC voltage and current required to operate the servo drives. The spindle drives have this same requirement and this "feature" cannot be bypassed or shut off.

The second problem with adjustable speed drives is that they are solid state in nature, so they will simply not standup to high voltage spikes phase to ground. All solid-state power supplies and adjustable speed drives cause a high content of harmonic noise and phase voltage distortion that affects their operational reliability. They cause of a lot of their own problems, as high frequency noise will confuse them and they simply lockup. If powering down and powering up resets the problem, generally it is power related.

The high voltage spikes (transient voltage events) can be caused when there is an intermittent ground in an ungrounded distribution system. The phase voltages become unbalanced to ground causing an imbalance exceeding the 10% requirement and stopping most, if not all the machines powered by the power transformer. The facility power system has the (2) power transformers connected in parallel, the problem is twice as large and it is seen everywhere both transformers feed. A ground anywhere on the system will be seen everywhere on the system as they are paralleled through the substation.

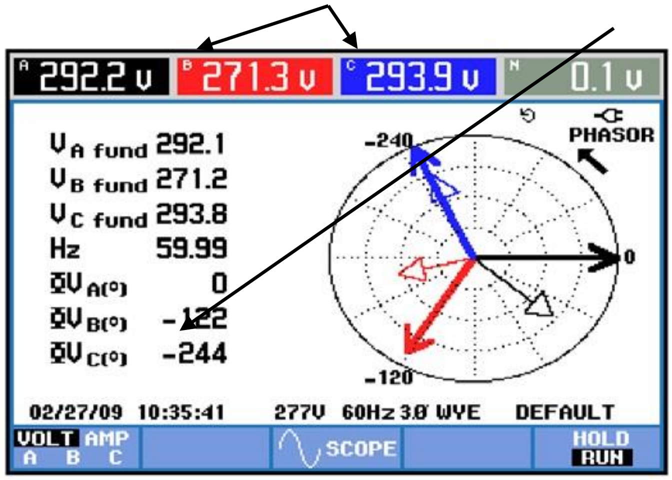
**Graphs with recorded data**

- After the data was analyzed, some interesting discoveries were made. The voltage phase to ground has a large harmonic content (see the graphs below). Running a harmonic spectrum on this waveform reveals the level of noise being filtered out with the Phaseback. The data (Voltage Harmonics) shows the noise filtered having a fundamental frequency of 106.1 MHz with harmonics through 14,429.6 MHz (14 gigahertz). This noise energy could be coming from various sources but most likely the nonlinear loads; power supplies, servo drives, spindle drives and controls are the cause. Note: 1 gigahertz = 1 000 000 000 hertz

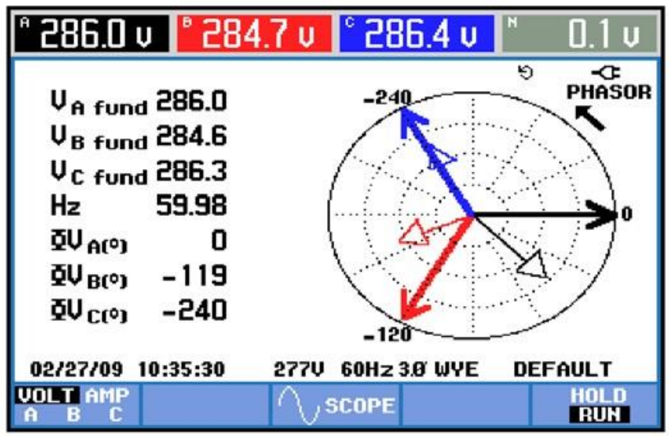



**The main power feed is derived from (3) single-phase 480 volt power transformers forming a 480 volt three-phase Delta secondary. This transformer bank powers most of the main facility. The power system supplies the power to hundreds of motor circuits through an old wiring system. The enclosed waveforms, screen shots and data clearly show a phase voltage imbalance of over 20 volts, transient voltage spikes, arcing ground-faults, increased harmonics and frequency instability. These are all electrical noise.**

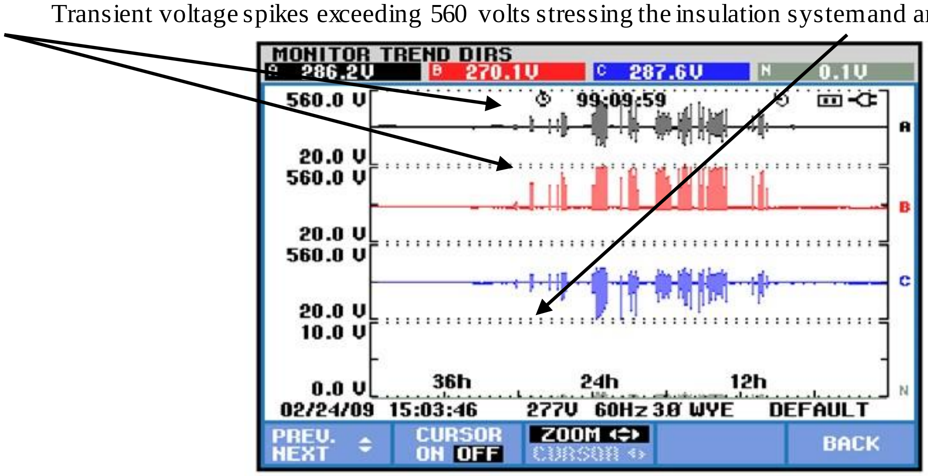
**Diagram shows a phase voltage imbalance of over 20 volts and phase shift of 4 degrees**



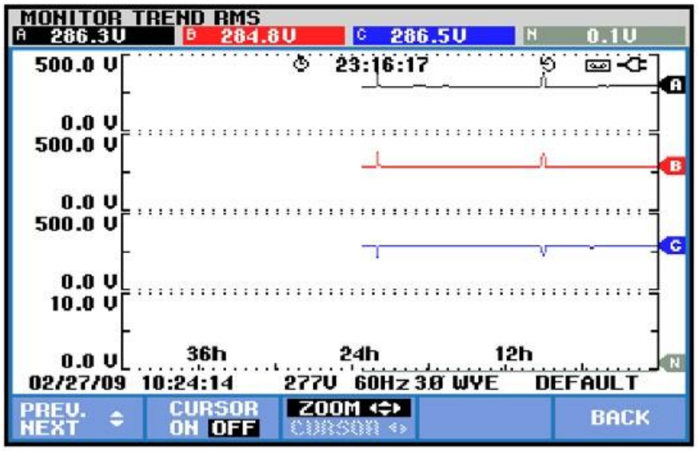

Power feed with the phase voltages balanced and stabilized with Phaseback



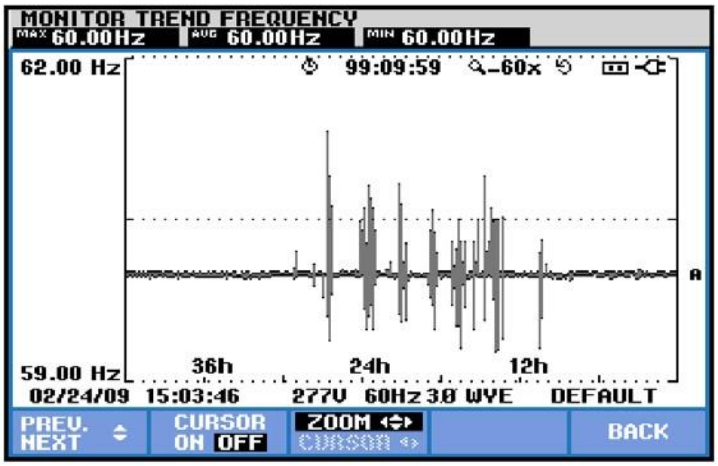

Transient voltage spikes exceeding 560 volts stressing the insulation system and arcing ground-faults



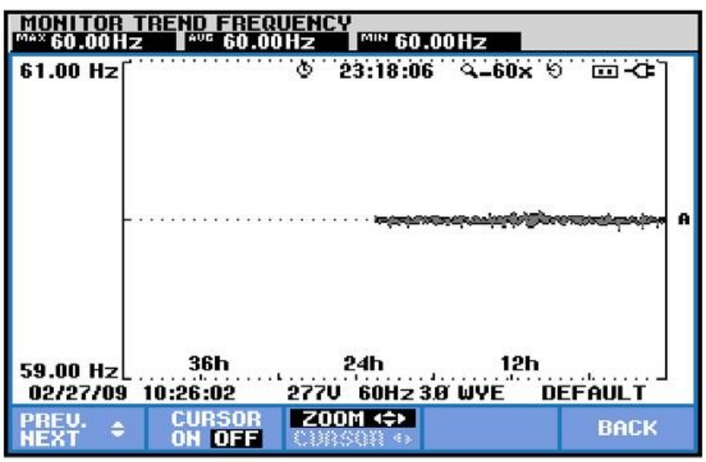

Phase Voltages balanced and stabilized with Phaseback




Frequency unstable and noisy from the voltage spikes and arcing ground-faults




Frequency stabilized with Phaseback

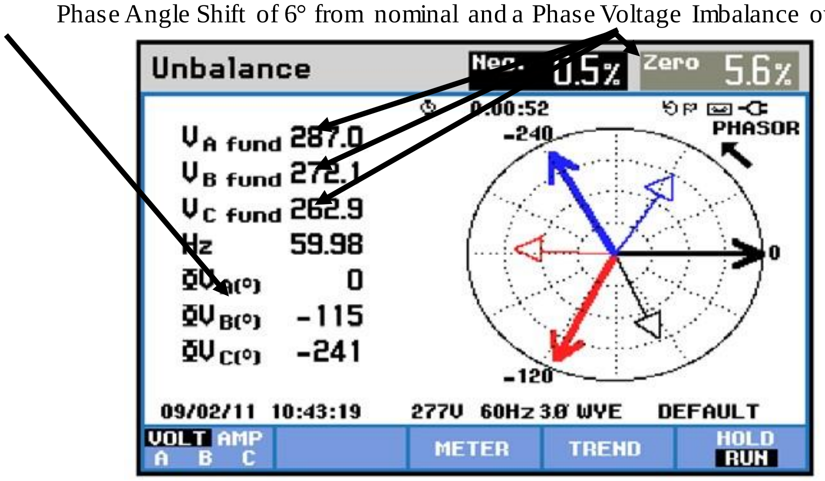



The following facility was using 350 kVA "wave trap" filters on eqch large machine with little success, extensive capacitor and equipment damage, downtime and ineffecient operation.

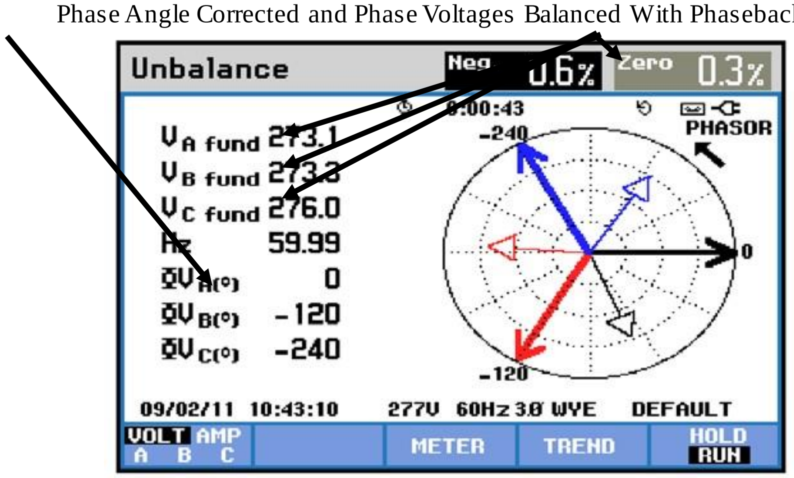
The following grapha and waveforms clearly show the improvements when a Phaseback VSGR was installed. The Phaseback uses less than 1 amp to correct these power issues.

Power Quality Testing on the Extruder Machine Power Feed

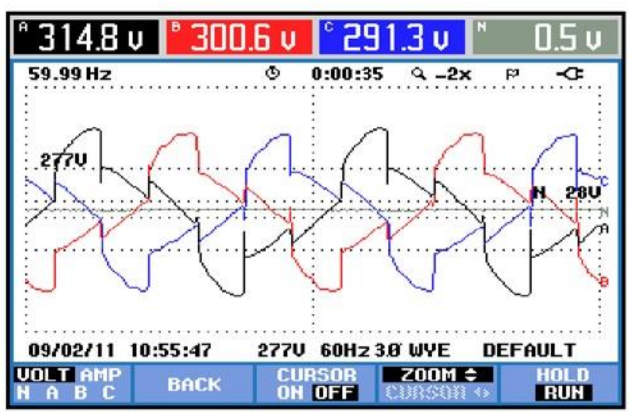
Phase Angle Shift of 6° from nominal and a Phase Voltage Imbalance over 5%



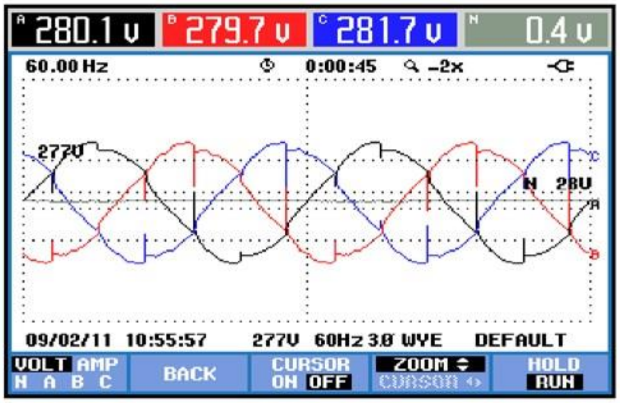

Phase Angle Corrected and Phase Voltages Balanced With Phaseback ON




Phase Voltage Notching Causing Waveform Distortion with Phaseback OFF




Phase Voltage Waveform Distortion Reduced with Phaseback ON




The COMSTA in Kodiak Alaska was having power supply, transmitter and power transformer failure. Every similar communication systems without Phaseback continues to have these problems.

Bill,

The tower we have Phaseback on is called COMSTA (Communication Station) it is the Radio Communication Station for the entire Alaskan Fishing Fleet making it a critical installation and we have Phaseback connected for 4 years now with no problems since the installation.

Dan.

Serious Arc-Flash and power system failure on work boats prompted a fast reliable solution.

Dan,

Here is a quick synopsis of my recent job using Phaseback solutions to restore system balance and provide arcflash prevention.

The site is a commercial maritime vessel used in the off-shore industry. It is heavily dependent on ungrounded voltage systems for service continuity. You can consider this a true, “No-Break” system, which means these voltage systems MUST tolerate phase grounds without danger to personnel, AND WITHOUT allowing loss of control system authority due to the inherent danger to operating equipment and operating personnel. Two arcflash events occurred recently while electrical workers were in the process of operating large circuit breakers. In each incident, the same breaker failed explosively, initiating the events. Several workers were injured, one seriously.

A total of four Phaseback units were purchased and installed; two on 690v systems and two on 480v systems. The Principle project electrical engineer (from Europe) enthusiastically endorsed my selection, agreeing that if the unit will stabilize the system voltages, then arc-flash events cannot occur. We proved this by installing one 690v unit, and then forcing a ground on one phase. The grounded phase voltage only dropped 2 volts! At this point, four more Phaseback units were purchased for a second vessel of the same design.

A large part of this task was to demonstrate to the ship crew that it was now safe to operate the equipment. The demonstration of Phaseback capabilities did this.

During the remainder of this job, Phaseback saved us two additional times. A large, 2.5MVA VSD system twice suffered catastrophic failure and subsequent grounding of a DC link snubber resistor (375kW). When this happened, since the VSD is powered from the 690v system, the DC went to the ship's hull and we believe this was the cause of the earlier arc-flashes.

The Phaseback is credited with preventing possibly major damage to the equipment and injury to personnel.

Thanks, and you have a great product!

# 200hp pump motor DVS Test May17_2010 Revised with new data

1) Current values from Graph Page 1 **Line Current with Phaseback DVS OFF and ON**

Current reduction: ( (62.7 + 64 + 63) ÷ 3 = (**63.23A**) **DVS OFF** ) - ( (60.9 + 60.6 + 60.4) ÷ **3** = (**60.63A**) **DVS ON** ) = 2.83A ÷ 63.23A = **4.48%**

Current (Summer) ( 155A ) - ( 148A ) = 7A÷155 = **4.5%**

2) Voltages from Phaseback DVS Analysis Data

3) Line Voltage with Phaseback DVS OFF (167x1.732=**289V**) DVS ON (160x1.732=**277V**) May17th

| | Phaseback DVS **OFF** | | Phaseback DVS **ON** | |
|---|---|---|---|---|
| Line Voltage | 289V | − | 277V | = 12 ÷ 289 = 4.15% Reduction (Calculated from Phase voltages) |
| Line Voltage: | 242V | − | 218V | = 24 ÷ 242 = **9.9%** Reduction (From Recorded Data) |
| Line Volts @ Load | 380V | − | 342V | = 38 ÷ 380 = 10% Reduction (Summer Load**)** |
| **Phaseback DVS** | **OFF** | | **ON** | |

**4)** Voltage Harmonics from B103 *Figure 2.1* **Harmonics with Phaseback DVS OFF and ON**

| | Phaseback DVS OFF | | Phaseback DVS ON | |
|---|---|---|---|---|
| **Total Harmonic Distortion (THD)** | **58%** | **−** | **47%** | **= 11 ÷ 58 = 19% Reduction** |
| **Line Voltage 2nd Harmonic** | **18%** | **−** | **3%** | **= 15 ÷ 18 = 83 % Reduction** |
| **Line Voltage 3rd Harmonic** | **9%** | **−** | **2.5%** | **= 6.5 ÷ 9 = 73% Reduction** |
| **Line Voltage 5th Harmonic** | **19%** | **−** | **16%** | **= 3 ÷ 19 = 16% Reduction** |

4) **Power (kW)** Voltages from item #2 above and Current from Item 1 above based on May17th Graphs

( (289V x 63.2A x 1.732 x.5) ÷ 1,000 = 15.8kW — **Phaseback DVS OFF** ) **-** ( (277V x 60.4A x 1.732 x.5) ÷ 1,000 = 14.48kW — **ON** ) = **1.33kW**

1.33kW ÷ 15.8W = **8.4%** **Reduction**

5) **Power (kW) Summer Cooling Season** Voltages from item #2 above and Current from Historical Data

( (380V x 155A x 1.732 x .8) ÷ 1,000 = 81.61kW — **Phaseback DVS OFF** ) **-** ( (342V x 148A x 1.732 x.8) ÷ 1,000 = 70.13W — **ON** ) = **11.48kW**

11.48kW ÷ 81.61W = **14%** **Reduction**

## Annual Payback based on 12 month operation using recorded and historical data

The payback uses the Line Voltages and Voltage Harmonics from the Phaseback DVS Analysis Page 3 of 5 however the Current is from Item 1 above, current trend over time to show the actual transition of Phaseback OFF/ON with properly sized current clamps for high resolution and accuracy

Line Voltages recalculated based on May 17$^{th}$ data Graph phase voltage averaged x 1.732 above

Typical running current from Graph and Line Voltages above

Typical Summer running current (155 amps) from historical data and (155A - 4.48% = 148A) based on current reduction percentage from item 1 from actual test data

Line Voltages @ Summer Load is 380 Volts per recorded Data

Typical power factors from testing (aprox .5 at 66 amps and .8 at 155 amp summer load)

Typical Running Load without DVS (13.25kW)

Typical Running Load with DVS (11.4kW)

Power reduction 13.25kW – 11.4kW = **1.33kW**

Typical Summer Running Load without DVS (81.61kW)

Typical Summer Running Load with DVS (70.13kW)

Power reduction 81.6kW – 70.13kW = **11.48kW**

1.33kW reduction x 4380 hours in 6 months = 5,825.4kWHr

11.48kW reduction x 4380 hours in 6 months = 50,282.4kWHr

Total Annual kWHr reduction 5,825.4kWHr + 50,282.4kWHr = 56,107.8kWHr

56,107.8kWHr x $0.075 per kWHr = **$4,208** annual energy savings

56,107.8kWHr x $0.080 per kWHr = **$4,488** Power Company Rebate Program

**$4,208 + 4,488 = $8,696** savings per motor per year

Every set of recorded data from various sources all correlate and are in the same ballpark. Payback calculations from our currents and voltages, our calculated voltages or historical voltages and historical currents all calculate to under a 1 year payback for a Phaseback DVS on one 200hp motor operated from one VSD.