Protecting Power System Infrastructures from Arc Flash and Voltage Instability

APPLIED ENERGY LLC

Executive Summary

This white paper presents an overview of common issues impacting power system infrastructures, their causes, and how Phaseback prevents these issues from inflicting damage to US power systems from transmission to end users.

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Why Prevention is Critical

In the United States, reliance on electrical power is greater than ever before. However, the grid's generating capability, distribution, and end user systems are all susceptible to major imbalances and damage caused by terrestrial weather events, geomagnetic disturbances, potential enemy attack, and everyday usage by its customers.

At present, the systems offered to solve power problems such as transients, harmonics, and outages are of limited effectiveness, and do not eliminate the source of the problem. What is needed is a solution that prevents the damage caused by the problem so it never returns. The solution must be one that performs this function without failure. It needs to be available at all voltage levels from low voltage to the high KV voltage level.

Power quality problems affect every part of America's economy. According to the latest studies, these problems annually cost over $150 billion. Designing prevention-based solutions is the best way to eliminate these massive costs.

4 Common Power Problems

In order to effectively protect all power systems, one must first identify the cause of the most pervasive power problems and understand their impact. While these problems are most commonly found in end user systems at the low voltage range, they can also be found in utility generation as well as distribution systems.

4 of the 6 most common issues in a power system as defined by IEEE:

1. **Arc Flash**
2. Transients
3. Interruptions
4. Frequency variations

Eliminate Causes of Arc Flash

Arc flash is caused by unrestrained ground faults that allow copper to heat to a plasma state. After a few milliseconds, it becomes an unquenchable plasma fire. One cubic inch of copper will expand almost instantly into seven cubic feet of 35,000°F superheated gas. The resulting pressure wave can crush a worker's chest. An arc flash study by the Department of Labor showed that in a 7-year period, 2,576 U.S. workers died due to arc flash incidents, and another 32,807 sustained lost time injuries, losing an average of 13 days away from work.

There is finally a solution to the causes of arc flash. Adding a Phaseback Voltage Stabilizing Ground Reference (VSGR) to the power system prevents the three causes of an arc flash event:

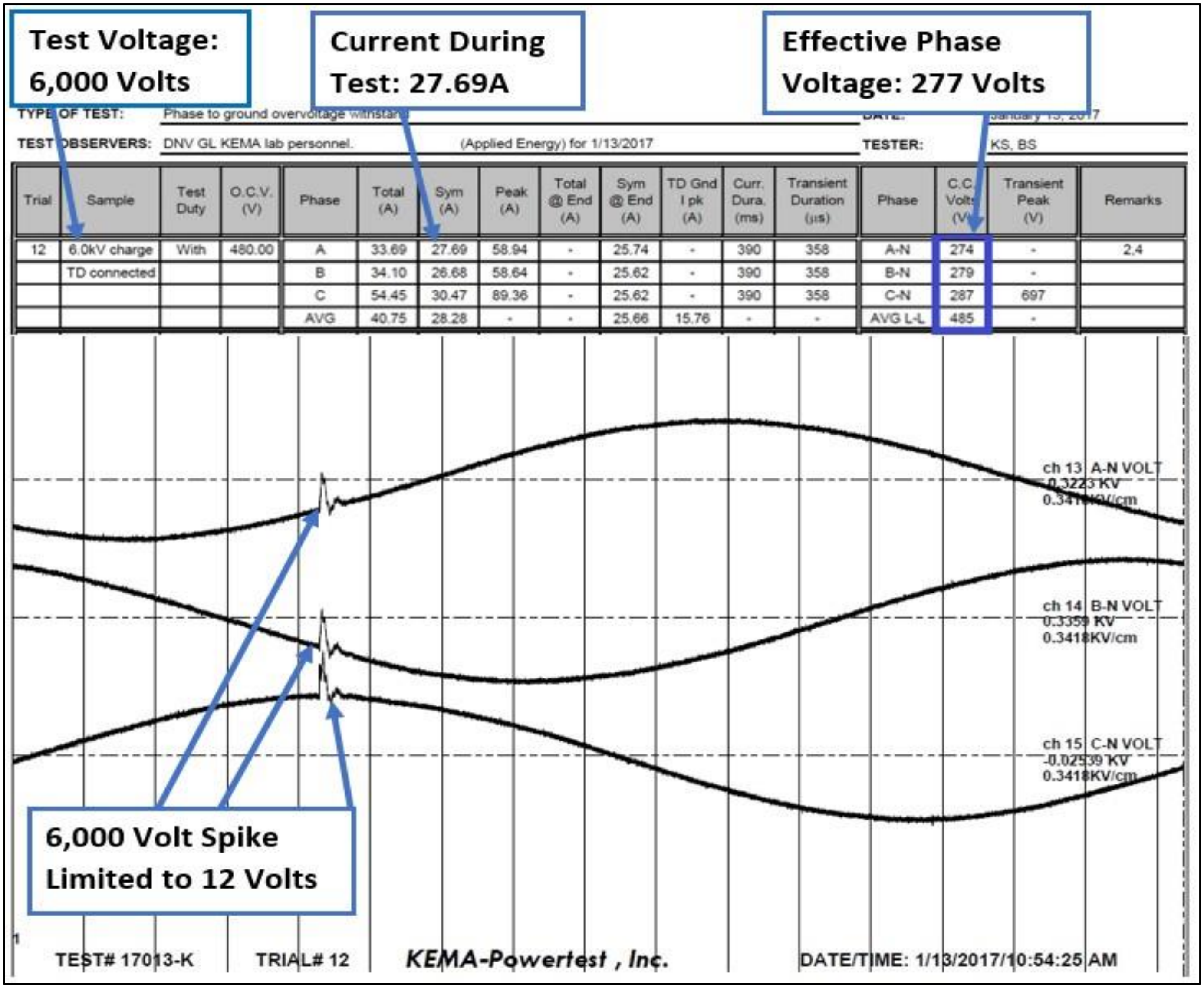
- Transient Voltage Spikes
- Arcing Ground Faults
- Phase Voltage Imbalances

With all three of these causes controlled and prevented, the insulation breakdown associated with arc flash no longer occurs. Prevention is the ultimate suppression.

Phaseback: The Only Proven Arc Flash Prevention Product

On January 13th 2017, Phaseback VSGR's resilience against arc flash events was tested at the KEMA high-voltage laboratory in Pennsylvania. A battery of arc flash tests were performed against the VSGR. The result: no damaged equipment, no arc flash, and no hazardous rise in voltage.

In the graph depicted below, the VSGR mitigated a test charge of 6,000 volts with a resulting rise of only 12V. In doing so, the VSGR consumed 0.25 amperes of current.



Trial	Sample	Test Duty	O.C.V. (V)	Phase	Total (A)	Sym (A)	Peak (A)	Total @ End (A)	Sym @ End (A)	TD Gnd I pk (A)	Curr. Dura. (ms)	Transient Duration (µs)	Phase	C.C. Volts (V)	Transient Peak (V)	Remarks
12	6.0kV charge	With	480.00	A	33.69	27.69	58.94	-	25.74	-	390	358	A-N	274	-	2,4
	TD connected			B	34.10	26.68	58.64	-	25.62	-	390	358	B-N	279	-	
				C	54.45	30.47	89.36	-	25.62	-	390	358	C-N	287	697	
				AVG	40.75	28.28	-	-	25.66	15.76	-	-	AVG L-L	485	-	

Transients

When someone says their power system has experienced a power surge, they are referring to an impulsive transient. Numerous terms have been used to describe impulsive transients, such as bumps, glitches, or spikes.

The causes of impulsive transients include lightning, poor grounding, the switching of inductive loads, utility fault clearing, and electrostatic discharge. The results can range from the loss (or corruption) of data to physical damage of equipment. Of these causes, lightning is probably the most damaging.

Interruptions

An interruption is defined as the complete loss of supply voltage or load current. The causes of interruptions can vary, but are most likely the result of some type of electrical supply grid damage, such as lightning strikes, animals, trees, vehicle accidents, destructive weather (high winds, heavy snow or ice on lines, etc.), equipment failure, or a circuit breaker tripping. While the utility infrastructure is designed to automatically compensate for many of these problems, it is not infallible.

Frequency Variation

There are many kinds of frequency issues from offsets, notching, harmonics, and inter-harmonics; however these are all conditions that occur largely in the end user's power system. These variations happen because harmonics from loads are more likely in smaller wye type systems.

The high frequency variations that may lead to massive interconnected grid failure would come from the sun or from enemy attack. Damage to only a few key infrastructure components could result in prolonged blackouts and collateral damage to adjoining devices.

Solar flares are natural occurrences that vary in severity and direction. This "solar weather" is sent out from the surface of the sun throughout our solar system in all directions. These flares contain large amounts of magnetic energy, and depending on how they hit the earth, can cause component damage on the surface or could temporarily change the properties of the planet's magnetic core. Either way, a direct hit of large proportion could cause equipment failure and black out entire regions.

Electromagnetic Pulses (EMP) can be used in similar fashion, but would be directed by enemy combatants in the form of a high altitude nuclear explosion. For example, a well-executed detonation over Cincinnati, Ohio could black out 70% of the American population. Damage to large power transformers or generators could take months to repair. The high frequency disturbance of nuclear explosions can destroy unprotected components much like an opera singer's voice can break a glass.

The magnitude of each disturbance may depend on the source, but each can be mitigated effectively through the use of the electro-magnetically operated phase voltage stabilization Phaseback.

Phaseback's Design

Phaseback is the only solution that focuses on prevention. The major difference in the design of Phaseback versus traditional surge protectors is that Phaseback operates at the speed of current flow to correct the voltage potential in relation to ground rather than draining current to ground.

By its patented design, Phaseback continuously stabilizes voltage relative to ground within a power system without using solid state technology like metal oxide varistors (MOVs). Phaseback reacts at the speed of current flow, which prevents power buildup, and mitigates arc flashes. Phaseback does not allow voltage leakage, nor will transient events degrade its performance as is seen in MOVs.

With Phaseback, utility company linemen will feel more secure due to the increase in power line stability while working on them, since arc flash incidents will become distant memories.

The components (matched single phase transformers) in this permanent solution are sized by the voltage class and kVA in which they will be employed. The voltage specification determines the appropriate turn ratios needed to properly size each system. All three transformers are spaced from one another according to IEEE standards to prevent arcing or magnetic flux between each phase. Ohm's law explains how power reacts proportionately regardless of scope: Phaseback's effectiveness would be the same in a 300kV system as it is on a 480V system.

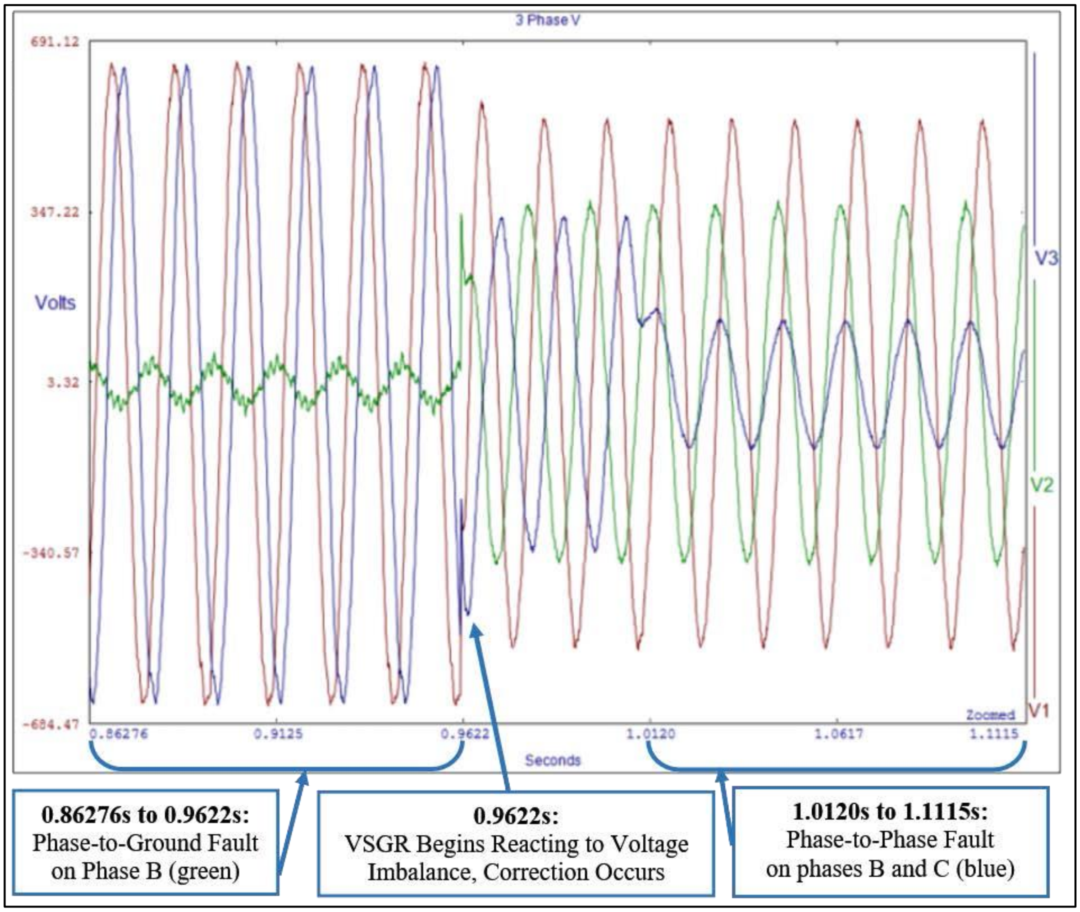
Phaseback systems all come in a NEMA type 3R enclosure with appropriately sized integrated fused disconnects. Phaseback is wired in parallel to the power system, and protects from the secondary side of a power transformer to the primary side of the downstream transformer. This also rings true from the generation source to the primary on the initial transformer.

All connected components would be protected, and Phaseback would maintain the voltage stability between phase and ground, preventing damage caused by downstream activity, or directly on line. No power system would need to be turned off to connect Phaseback: linemen could hot tap them into the system, then engage Phaseback using the disconnect switch.

Phaseback Prevents Arc Flash, Even in a Worst-Case Scenario

According to the IEEE, the vast majority of phase-to-phase faults start as either phase-to-ground faults or flashover due to insulation breakdown. Before Phaseback VSGR, a phase-to-ground fault or flashover would inevitably result in an arc flash event.

The graph below depicts a phase-to-ground fault which led to a phase-to-phase fault. No arc flash occurred. Phaseback VSGR mitigated the arc flash condition!



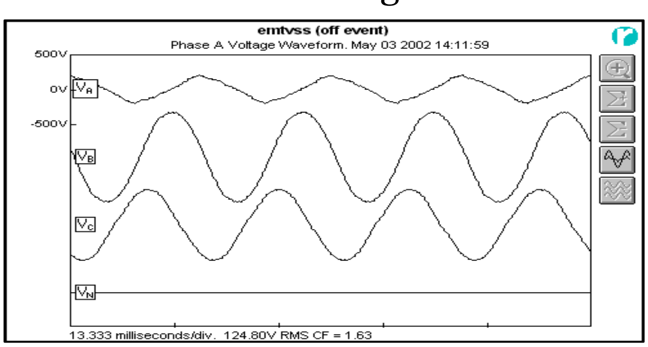
Phaseback Detected and Corrected Grounds on Two Phases without an Arc Flash Incident

How Phaseback Protects

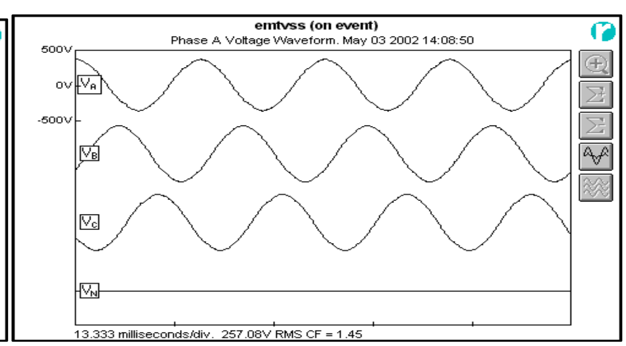
Focusing on voltage allows Phaseback to address each of the 4 Common Power Issues. Let's see how it would correct each of those issues individually.

Transients are the brief voltage spikes that occur regularly and may last only a few cycles. Phaseback stabilizes the voltage so no current can flow, preventing damage caused by current flow. With a power analyzer, one could see that disturbances placed directly on line are completely mitigated.

Voltage Phase to Ground with Phaseback



Phase voltage 61% imbalance with Phaseback OFF



Phase voltage imbalance 6% with Phaseback ON

Interruptions have many causes, but the damage occurs in the brief moments when a system loses power. During a power loss, motors wind down and temporarily become mini generators, sending inappropriate voltages to connected loads. Phaseback would not prevent sustained power losses, but would prevent damage to loads by allowing a softer landing should an outage occur.

The Phaseback system would also reduce the harmful effects of voltage instability like sags, swells, or under/over-voltage. The primary sides of the transformers and their adjoining secondary constantly stabilize the voltage discrepancy. Conventional surge suppressors and MOV systems route power to ground, which can cause an unsafe condition, and surely reduces the life of the device and connected loads.

Waveform and frequency variations might best be described as noise on the line from massive magnetic forces. These magnetic hits to the grid can cause damage to generators, transformers, auto tapping devices, and connected loads throughout. High frequency noise from hostile EMPs change the normal 60 Hz flow of electrons, which may wreak havoc on infrastructure. Depending on the severity or proximity to such hostilities, damage could range from loss of end user electronic devices to the overheating of the stators on utility generation plants or power transformers. Phaseback would act as a gatekeeper, suppressing any frequency above or below the 60 Hz range. Without the Phaseback system, damage to grid components could occur in an instant, but since it operates only on 60 Hz waveforms, it routes the inappropriate waveform to the integrated resistor bank at the exact speed of the infraction.

Phaseback, therefore, rectifies disturbances that are out of specification, and harmonizes everyday activity.

Save Money and Lives

Facilities equipped with the Phaseback VSGR have seen it for themselves: power quality problems are no longer a cost of doing business. Premature equipment failure, arc flash hazards, and excessive energy consumption are no longer a fact of life!

Phaseback VSGR is the world's only energy-saving, energy-efficient, future-proof, harmonic noise eliminating, ground fault & arc flash preventing, lightning arresting, EMP mitigating, voltage stabilizing system. It is the only power quality product that produces a return on investment, typically within one year.

Phaseback is a scalable product. It can be engineered for power systems of all sizes and all voltage classes. Phaseback connects in parallel with the power system. Only one unit is needed for each transformer in an ungrounded Delta facility. One is required on the load side of a grounded wye and on the load side of each stepdown transformer. Phaseback is universally applicable: it benefits generation, distribution, industrial, commercial, military, and even residential power systems.

Since its patenting in 2005, Phaseback has been implemented for a wide variety of purposes, including military, industrial, and factory applications. **Phaseback has 15 years of continuous, fault-free operation in numerous applications.** All Phaseback products are backed by a lifetime warranty.

There is a limit to how much a company can compensate for financial losses by increasing the cost of its products or services. With the knowledge of what Phaseback can do for your facility, will you continue to allow power issues to rob your organization of its profits?

Applied Energy LLC is committed to proving ourselves as the only true power quality solution. All Applied Energy products are designed to enable proper utilization of power for our clients. Contact us at Applied Energy LLC to find out how we can help you.

References and Further Reading

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