Technology Assessment and Application Guide for an Active Voltage Conditioner with Storage Option (AVC-Store)

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REPORT SUMMARY

This report describes and documents the construction, performance, and application of an active voltage conditioner (AVC) with energy storage. The system—called the AVC-Store—is manufactured by Vectek in Napier, New Zealand. Composed of a novel power electronics module, the system is organized to mitigate voltage sags, phase shift, and outages. This report describes the various subsystems within the AVC-Store, its operation, results of characterization tests, and issues related to its application and installation.

Background
Although uninterruptible power supply (UPS) products continue to dominate the market for the mitigation of power quality events such as voltage sags, swells, outages, and transients, the AVC continues to expand its market share by offering load protection at an affordable price. In addition, the AVC is now offered with a storage option.

Objective
- To describe and document the construction, performance, and application of an AVC with energy storage

Approach
An engineer from the Electric Power Research Institute (EPRI) visited the Vectek facility in Napier, New Zealand, and over the course of several days received detailed training on the product and its operation. The engineer also served as a witness for the testing of various systems under simulated conditions.

Results
The AVC-Store is composed of a novel power electronics module and is organized to mitigate voltage sags, phase shift, and outages. The system met all expectations and typically has a payback period of less than one year.

EPRI Perspective
By providing utilities with a technical understanding of the performance and application of the AVC-Store, EPRI is enabling them to better service numerous key customer segments. With knowledge of this state-of-the-art technology, electric utilities are in a unique position to help their clients to value and implement new power quality mitigation solutions. Such solutions may be better and more cost-effective than solutions based on traditional technology.

Keywords
Power quality
Active voltage compensation
Energy storage
Voltage sag
Voltage interruption

CONTENTS

1
INTRODUCTION

Company Overview

VECTEK Electronics Ltd. is a group of companies located in Napier New Zealand. VECTEK commenced trading in 1992, specializing in marketing industrial control equipment. In October of 1995, VECTEK introduced the Omniverter family of products, which included ac drives, power quality products, and power-conversion equipment. The current product offerings include uninterruptible power supplies (UPSs), an active voltage conditioner (called the AVC-Store), and power-factor-correction devices.

VECTEK's principal area of expertise is in the application of microelectronic control techniques to three-phase power equipment and systems. Their core competency encompasses the application of high-power electronic converters, IGBT Inverters, SCR transfer switches, embedded control software, and high-speed, broadband control. Combined, these advanced technologies are used to create products that mitigate the effects of electrical disturbances.

VECTEK is a privately owned company controlled by directors Keith Valentine, Murray Porteous, Simon Walton, John Penny, and Vernon Pryde. The company is supported by a high-tech staff with years of experience designing and manufacturing power electronic solutions for industry.

VECTEK has established a network of international distributors supplying their products and services to industry located in Australia, South East Asia, Korea, India, Europe, the USA, and Canada. The distributor/partner within North America is the Canada-based Omniverter, which is lead by David Ezer and Ian Ross. Vectek claims to be the world's largest supplier of high-power sag-mitigation equipment with an installed base of hundreds of units.

The engineers at Omniverter work with prospective customers to identify power quality issues. Moreover, they help to increase awareness within industry of the high cost in terms of lost material, lost labor, and, in plants operating at close to capacity, lost sales opportunity. They provide a financial model that is easily tailored for individual customers using site-specific data to calculate return-on-investment (ROI), as shown in Figure 1-1 [1]. Once the amount of avoidable cost is calculated, Omniverter provides evaluation software to aid in determination of optimal solutions. Omniverter reports several installations with complete payback of investment within one year of installation [2].

Figure 1-1
Omniverter Software Used to Calculate Cumulative Avoidable Costs Due to Voltage Sags (Example Data Only)

System Description for AVC-Store

The AVC-Store is second generation technology that builds upon VECTEK's proven AVC product line originally presented in EPRI's March 2004 technical update titled *Technology Assessment and Application Guide for Emerging Power Quality Mitigation Hardware: Energy Storage and Power Electronics for Power Quality Solutions Program* [3]. A preliminary data sheet for the AVC-Store is included in Appendix A. Photos of the power electronic and control cabinets are shown in Figure 1-2 and Figure 1-3. The main subsystems within the AVC-Store are shown in Figure 1-4 and are discussed below.

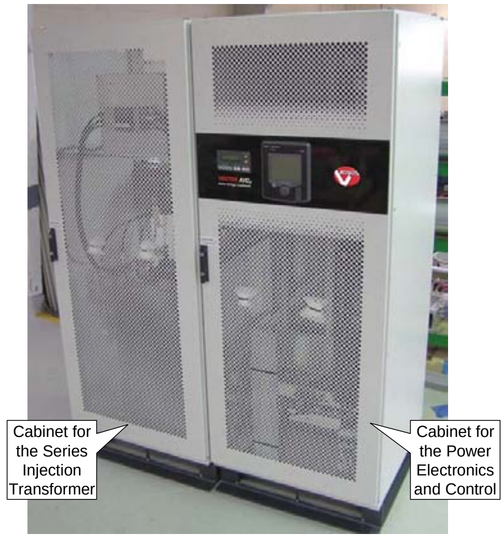

Figure 1-2
Exterior of the Power Electronic and Control Cabinet for the AVC-Store

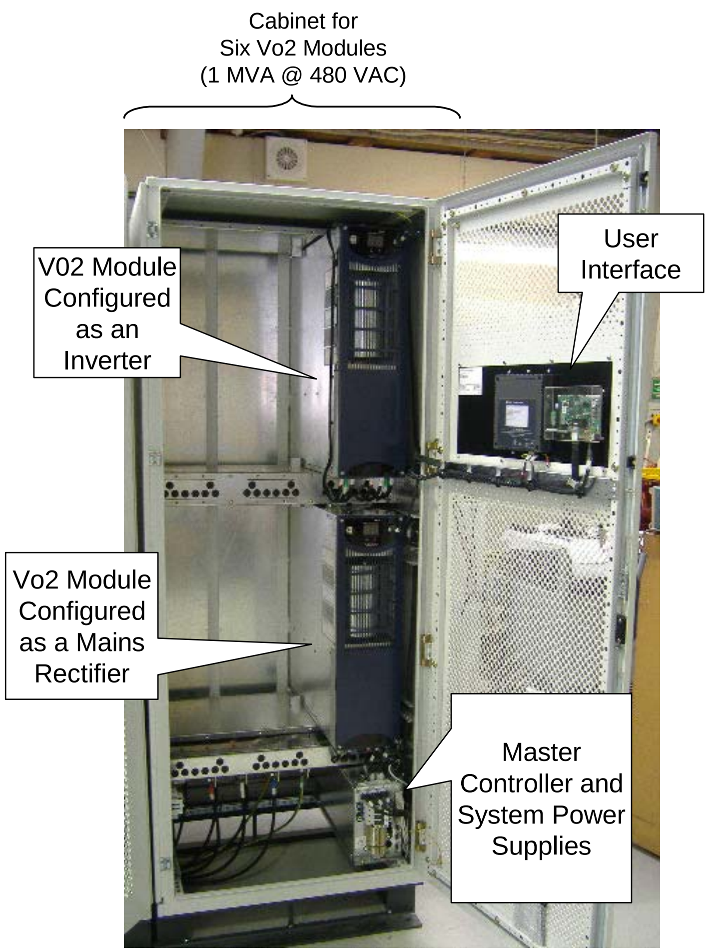

Figure 1-3
Interior of a Partially Assembled Power Electronic and Control Cabinet for the AVC-Store (Static Switch and Parallel Inverter Not Shown)

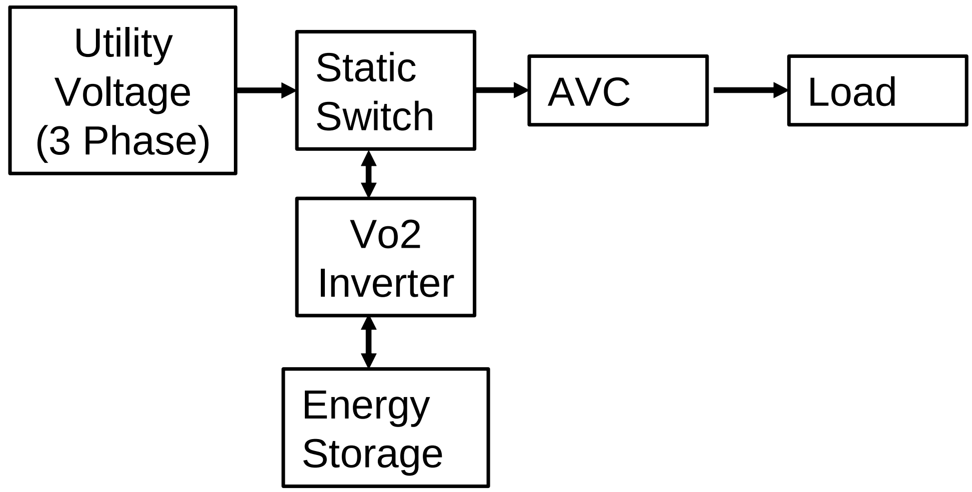

Figure 1-4
Simplified Schematic Showing the Main Subsystems with the AVC-Store

Static Switch

The static switch is used to seamlessly change to a backup energy source when the monitored utility voltage exceeds a predefined voltage window. For example, consider an AVC designed to compensate for a sag in voltage down to 70% of nominal. If the utility voltage drops below 70%, in order to maintain protection to the load, the static switch transfers power flow from the utility voltage to the stored energy source via the parallel-connected inverter (Vo2). If the utility voltage recovers before the energy source is exhausted, the static switch will transfer back to the utility voltage.

The static switch uses the latest silicon-controlled rectifiers (SCRs) combined with advanced digital signal processing (DSP) and software control. Fast transfer time of the SCRs is ensured because of a unique control algorithm that uses a feedback loop based on the commutation (turn off) of the SCRs rather than an open loop time-based algorithm. The net result is instantaneous, seamless transfer from one voltage source to another.

In the case of unique sensing and control requirements, because of the software-controlled logic rather than hardware-based logic to determine a line fault, the static switch can easily be customized. So, instead of adjustments to a control card, the software within the DSP can be optimized either at the factory, on site, or over an Internet connection.

AVC

The heart of the AVC is the series injection transformer, whose role is to either boost or, in this second-generation device, also buck the line voltage to maintain constant voltage at the output (see Figure 1-5 and Figure 1-6) [4]. To understand the concept, think of the AVC as a fast-adjusting variac in series with the utility voltage. When the utility voltage decreases, the voltage across the variac is increased to boost the voltage. Conversely, when the utility voltage swells, the voltage across the variac is either decreased or made negative to buck the voltage. Instead of a variac, however, a fast inverter is placed on the secondary (inverter side) of the series injection transformer. A monitoring circuit (not shown) continuously samples the input voltage looking for voltage deviation from nominal at the input of the AVC. If the voltage sags, the inverter increases its output to generate a compensation voltage across the primary winding of the injection transformer. The compensating voltage is the difference between the desired output voltage and the actual voltage received from the utility main voltage supply. Thus, the sum of the utility voltage and the compensation voltage equals the regulated voltage at the load. Under conditions of overload or when the rating of the system is exceeded, the series transformer is shorted using a bypass circuit, which consists of both an electronic switch (SCR) for fast response and a large contactor for long-duration bypass.

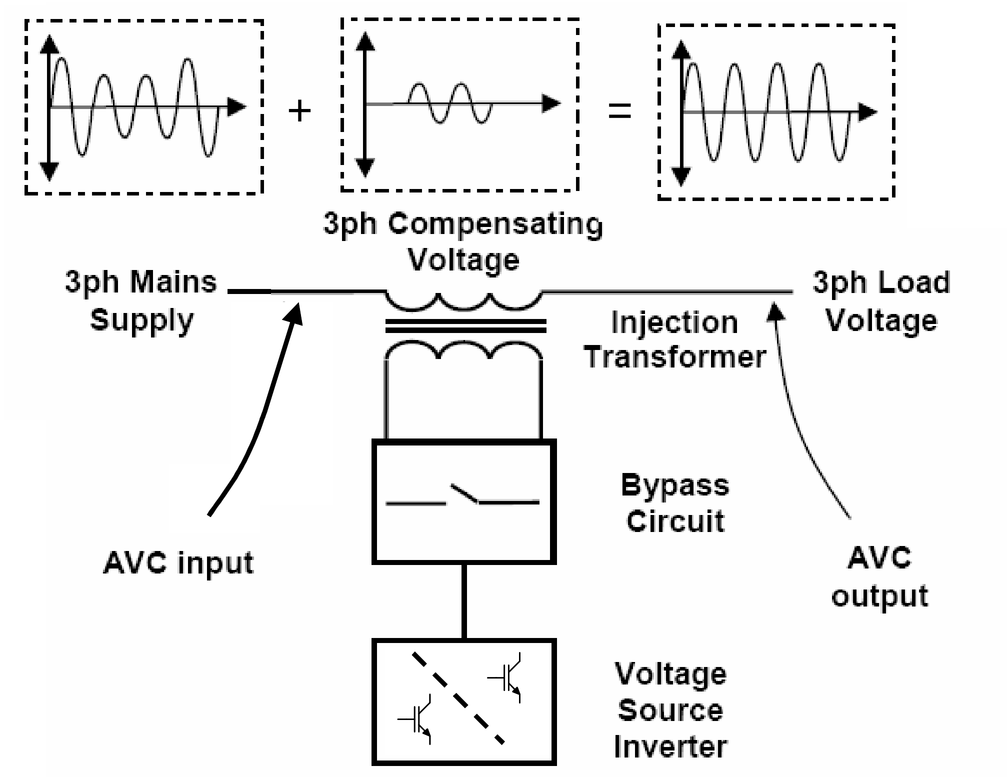

Figure 1-5
Simplified Schematic Showing the Arrangement of the AVC Within the AVC-Store

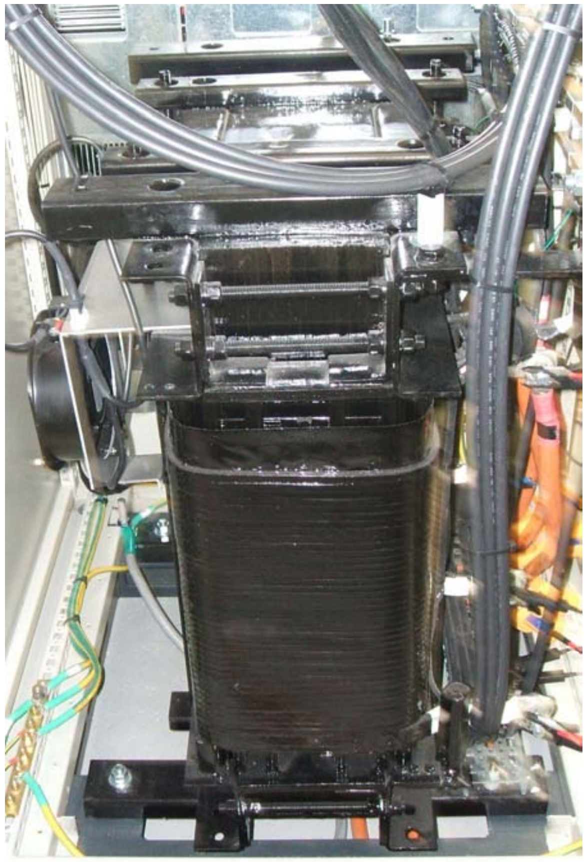

Figure 1-6
Series Injection Transformer of the AVC-Store

During a voltage sag, additional current is drawn from the main supply to maintain constant power to the load. During an overvoltage, just the opposite is true; current from the mains is reduced. This is easy to understand if you think about it in terms of constant power. We know that wattage is the product of voltage and current. So, if the voltage increases, in order for the same power to be drawn from the utility mains, the current must decrease. Likewise, if the voltage decreases, in order for the same power to be drawn from the utility mains, the current must increase.

The AVC is available in sizes ranging from 25 kVA up to 6 MVA in low-voltage models (<690 V) and sizes ranging from 1 MVA to 50 MVA in models up to 38 kV. Depending on configuration, the AVC can correct three-phase voltage sags to 50%, single-phase voltage sags to 25%, phase imbalance. The second-generation systems, which will be available the first quarter of 2007, will also provide correction against overvoltages.

An often overlooked characteristic of a three-phase voltage sag is the phase shift that occurs during the sag. Phase shifts typically result from an interaction between fault current and the impedance in the electrical distribution system [5]. A shift in phase will cause a three-phase motor to experience voltage unbalance and torque transients, as well as phase-controlled rectifiers to misfire. The result of a phase shift can be a shutdown, a clearing protective fuses, or, in a worst-case scenario, the failure of motor components. The ability to correct for a step-change in phase is a distinct advantage of an active voltage regulator.

The AVC-Store corrects for phase shift by continuously monitoring the three-phase voltages on the utility supply and comparing them with digitally-balanced sinusoidal-reference waveforms that are phase locked to the utility supply. A sophisticated DSP-based microcontroller calculates in vector form the differences between the utility supply and the reference waveforms. These error waveforms are then used to generate pulse-width-modulated (PWM) waveforms that control the IGBT switches in the inverter. After the waveforms are filtered, the correction voltage with the appropriate vector appears across the injection transformer, which is connected in series with the mains supply. In this way, the AVC system corrects for both phase and magnitude errors in the utility supply. Normally, a major voltage sag results in both a reduction in voltage and a step change in phase of the supply waveforms. The phase-lock-loop (PLL) of the reference waveform generator within the DSP is configured such that the reference waveforms slowly adjust in phase, allowing the voltage conditioner to correct for any step change in phase and thus minimizing the impact on sensitive loads.

A key innovation within the AVC-Store is the use of flux control within the inverter control loop. Previous versions of the AVC-Store used voltage, current, or both in conjunction with the error signal to correct for a voltage sag. The new design, by virtue of its powerful microprocessor, measures the instantaneous flux within the series injection transformer to optimize control and create the precise voltage at the precise phase angle to correct for any deficiency in the mains voltage.

Other advantages of an AVC are well known and include:

- Efficiency of regulation: With greater than 98% efficiency, an AVC produces much less heat than conventional solutions.
- Preferred failure mode: No power electronic component is in series with the utility. During a fault, the series transformer is shunted, allowing operation of critical loads to continue.
- High fault current capability compared to a traditional UPS to ensure operation of protective devices.
- Smaller footprint given that the power electronics are sized only for the correction voltage, which is typically 30% of the full rating of the connected load.

Voltage Source Inverter

Referred to by VECTEK as the Vo2, the voltage source inverter is used to convert the dc voltage produced by the energy storage to ac voltage used by the load (see Figures 1-7 and 1-8). It connects in shunt with the load through the static switch. The same module in a slightly different configuration is used as either a rectifier or inverter within the AVC.

Figure 1-7
Vo2 Module with Cover

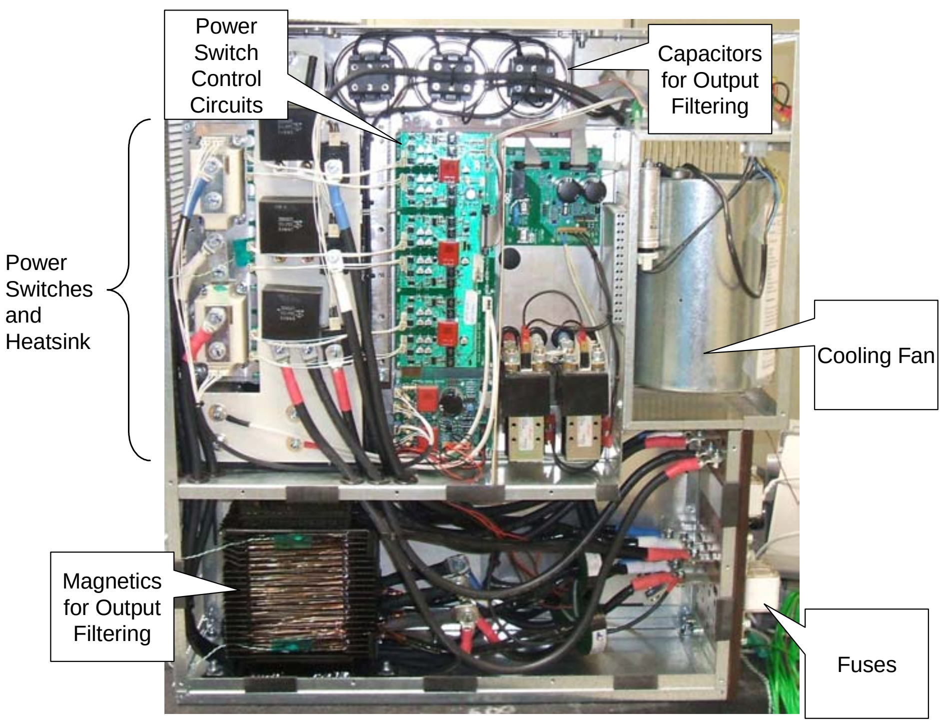

Figure 1-8
Side View of the Vo2 Module

The Vo2 is a new design of voltage source inverter that is optimized for flexibility via advanced software control. While the power electronics are basically the same, what has changed is the control method, which is based on a master controller that communicates to each Vo2 through a proprietary high-speed data bus. This serial backplane uses synchronizing control to coordinate switching of power switches. This means that all control signals for as many modules in parallel as needed originate at a central location. Central control simplifies maintenance and upgrading of modules. Like a parent, the central controller monitors the health of each module and keeps track of performance. Included with each master controller is a flash memory card that allows for simple software upgrades, allows for easy tracking of changes in configuration or set points, and in general serves as the network administrator, with the network consisting of the various Vo2 modules throughout the system configured as rectifiers and inverters.

An additional feature of the system is the integration with modeling software and automatic code generation. Using a SPICE-based simulation program, the engineers at VECTEK can run computer simulations of system performance using data gathered from actual installation sites. If changes are needed to the software, the changes are automatically written based on the changes made within the simulation program. This powerful feature allows for continuous improvement in product performance in response to the ever-changing electric environment in which the system must operate.

Furthermore, the design of the Vo2 is modular, a design choice that simplifies system design by allowing modules to be placed in parallel to achieve the desired power level. If a fault should occur within a module, it is sectionalized in the sense that it will not propagate to other modules. Local protection devices isolate the module. Designing the Vo2 for common levels of voltage and current enables the use of conventional fault-protection fuses that are readily available. Moreover, each Vo2 module is designed for rapid repair or replacement, with a typical time to replace less than one-half hour.

Energy Storage

Recognizing the need to provide a solution for applications that require more than just sag correction, VECTEK is offering the AVC-Store with energy storage, such as batteries, to provide short-term ride-through for interruptions. During a deep sag or outage, the stored energy is discharged to maintain power to the load. During normal utility operation, the batteries are charged.

A unique characteristic of the AVC-Store is its ability to operate from a variety of energy-storage devices, such as batteries, electrolytic capacitors, ultracapacitors, and flywheels. The feature that enables this is the ability of the Vo2 to accept a wide range of input voltage[1]. The real limitation is the current rating (150 A per module), not the voltage. So, for example, at 700 Vdc, the steady-state power rating of one Vo2 is roughly 100 kW (700 V * 150 A), but at 350 Vdc, the power rating is reduced to roughly 50 kW (350 V * 150 A). Further extending the power rating is the ability to operate the Vo2 in excess of 150 A for short periods of time, in effect allowing a duty-cycle rating. The flexibility in voltage allows for simple custom configuration of the AVC-Store for one or more energy-storage technologies. Achieving a desired power rating requires configuration of the Vo2 modules in parallel.

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[1] The Vo2 will accept 750 V continuously, 900 V peak.

2
CHARACTERIZATION TESTS

Test Description

What is important to the overall performance of the system is the ability to detect a deviation in utility mains voltage and respond accordingly. The AVC-Store monitors all three input phases. The decision to transfer to the parallel inverter and energy storage is based on the depth of the voltage sag. If the sag is within the correction window of the AVC, typically down to 70%t for a three-phase voltage sag, the static switch will stay connected to the utility mains. However, if the voltage on one or more phases sags below 70%, the system will initiate a transfer from utility voltage to the stored energy.

Objective

The objective of the on-site testing was to determine the performance of the AVC-Store system and its ability to operate as a ride-through device. It must be noted that the testing was not rigorous and was meant to communicate to the reader a basic verification of the device performance. When the principal investigator visited the factory in Napier, New Zealand (November of 2006), the AVC-Store was still under development and the final configuration of the system was not available. Testing witnessed on site during the November visit consisted of the following:

Response to Voltage Sags and Voltage Swells

The AVC-Store has an AVC to provide correction of both sags and swells. During the test, simulated utility sags and swells were applied to the system, and the output was monitored and recorded. The system was expected to seamlessly correct both sags and swells, maintaining regulated voltage and phase to the connected load.

Response to Interruptions

Events outside of the operational window will cause the static switch to operate, transferring the system to backup power. Artificial interruptions at various phase angles (point-on-wave) were applied to the system, and the output was monitored and recorded. The system was expected to seamlessly transfer to backup energy and prevent interruption to connected loads.

Stability

Given the claim of system flexibility with regard to choice of energy storage, the system must function from both a high- and low-impedance source. An example of a high-impedance source is a dc/dc converter that couples a flywheel system to the parallel inverter. An example of a low-impedance source is a battery that is sized to provide minutes of runtime. During the tests, the system was operated from both a low-impedance source (battery) and a high-impedance source (variac with rectifier) under steady-state conditions. The system was expected to provide stable voltage to the load.

Verification of DC Input Range

Given the claim of having a wide range of input dc voltage, the system must operate during both a condition of high and low voltage. A high voltage may result from a voltage supplied by the dc/dc converter of a flywheel. A low voltage may result from a discharged battery, electrolytic capacitor, or ultracapacitor. Under conditions of either high or low input dc voltage, the system was expected to provide stable voltage to the load.

Test Setup

The AVC-Store was performance tested at the VECTEK facility using two different systems:

- A prototype AVC-Store that consisted of a static switch, parallel-connected inverter, batteries, and AVC.
- A second system that consisted of only the next-generation AVC that made use of the Vo2 module (without static switch and energy storage).

The prototype system was used to demonstrate response to outages and the discharge of energy storage. The next-generation AVC was used to demonstrate the advanced features of the AVC, such as the ability to compensate for voltage swells in addition to voltage sags and the ability to correct for phase shift to maintain proper phase sequence both during normal operation and during transient events. Test data were collected with two Fluke 434 power monitors, a Hioki 3197 power meter, and Tektronic oscilloscopes with appropriate voltage and current probes.

Test Results

Response to Voltage Sags and Voltage Swells

Figure 2-1 shows a representative plot of the data collected during the application of a voltage sag down to 80% of nominal to the input of the AVC-Store. The data clearly shows a correction of the input voltage such that the output voltage is regulated for the connected load. During testing, it was noted that, as expected, the input current increased in response to the constant power draw from the combination of the AVC and load.

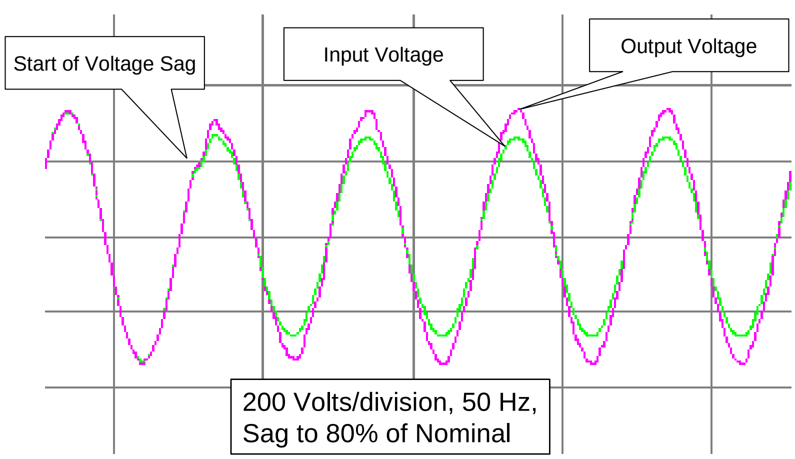

Figure 2-1
Representative Plot Showing the Response of the AVC to a Voltage Sag to 80% of Nominal

The results of the testing indicate that the AVC eliminates the need for the static switch to transfer to the parallel inverter and stored energy source during voltage sags. Thus, given that in many areas most power quality events are voltage sags rather than deep sags or outages, the number of cycles on the source of stored energy will be less, which may lead to a longer lifetime, depending on the storage technology used.

Response to Interruptions

Figure 2-2 and Figure 2-3 show a screen capture from two Fluke 434 power analyzers during which the power to the AVC-Store was interrupted using a contactor. The screens on the left show the three-phase voltage to the load. The screens on the right show the three-phase current drawn by the load. Figure 2-2 shows the interruption at a phase angle of approximately 130 degrees on phase A, and Figure 2-3 shows the interruption at a phase angle of approximately 180 degrees on phase A. Both figures clearly show that during both interruptions, the static switch transferred the load from the interrupted mains to the parallel inverter and stored energy, which in this case was a battery. The results of the testing indicate that the system successfully transferred from utility power to backup power with minimal disturbance to the quality of the output waveform.

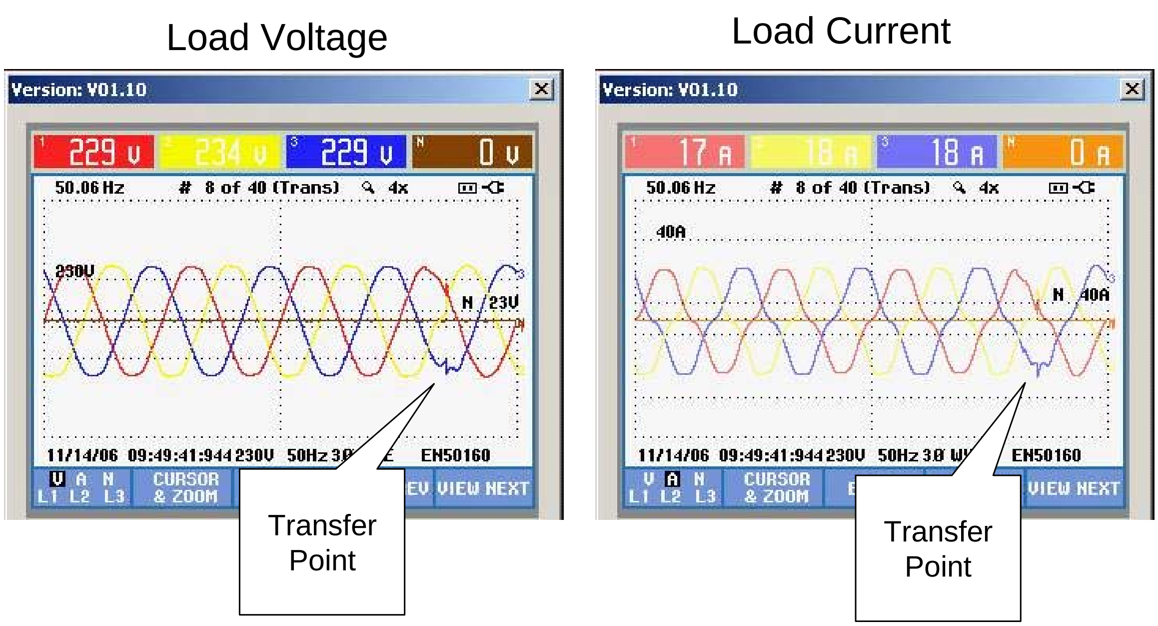

Figure 2-2
Screen Captures Showing the Load Voltage and Current During a Outage and Subsequent Transfer to Stored Energy

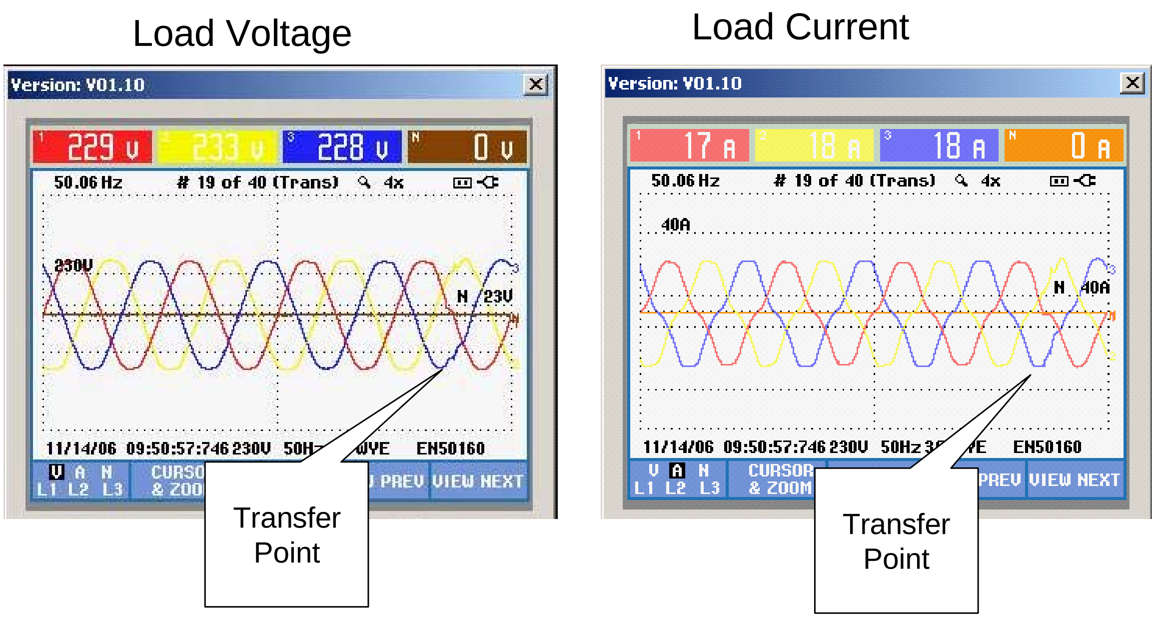

Figure 2-3
Screen Captures Showing the Load Voltage and Current During a Simulated Outage and Subsequent Transfer to Stored Energy

Stability

Figure 2-4 is a representative plot showing the stability of the system with the inverter operating and the source of energy storage discharging. The waveforms within the plot (load voltage on the left and load current on the right) indicate stable operation. Moreover, during testing, the system was observed to operate both from batteries (low-impedance source) and from the rectified output of a variac (high-impedance source). Under these conditions, the investigator monitored both an oscilloscope and a power meter configured to monitor the output voltage. In each case, the output was observed to be free from oscillation. Moreover, during transfer from utility, it was observed that the output of the variac did oscillate in response to the step load. However, the inverter of the AVC-Store was able to filter this oscillation and continue to provide stable voltage to the connected load.

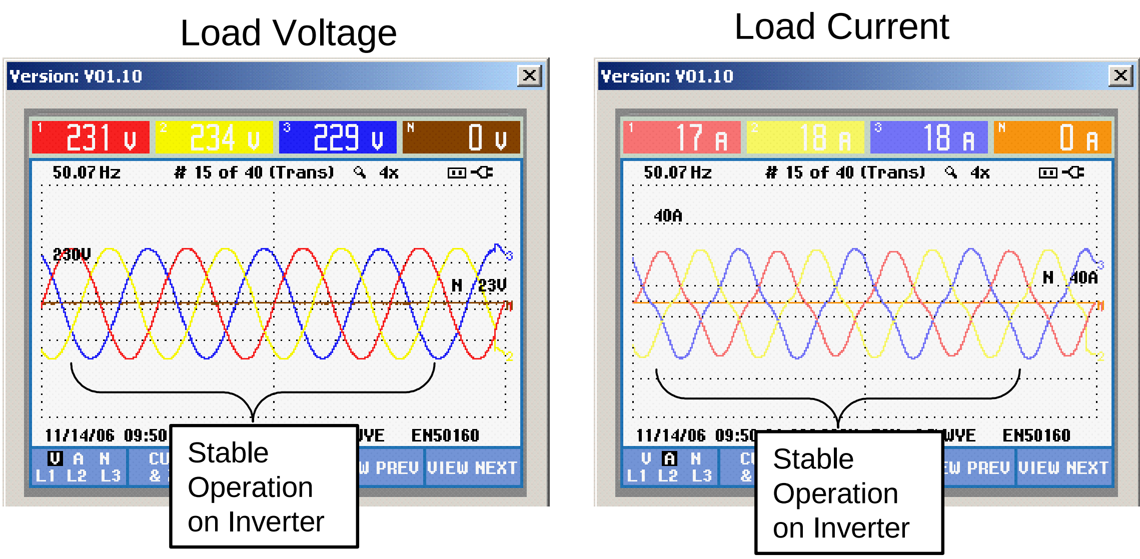

Figure 2-4
Screen Captures Showing Stable Operation of the System While Operating From the AVC-Store Inverter

Verification of DC Input Range

Given the equipment limitations of the test setup, it was not possible to demonstrate the entire operating range of the Vo2 module (which the manufacturer declared to be from zero to 750 Vdc). However, it was possible to demonstrate operation over the range of approximately 375 Vdc to 580 Vdc. (Note that 375 V represents 50% of 750 V.) Figure 2-5 is a plot of dc voltage over time as the dc voltage is varied from roughly 580 Vdc down to less than 400 Vdc. During this time, it was observed that all output phases were stable and at nominal RMS value.

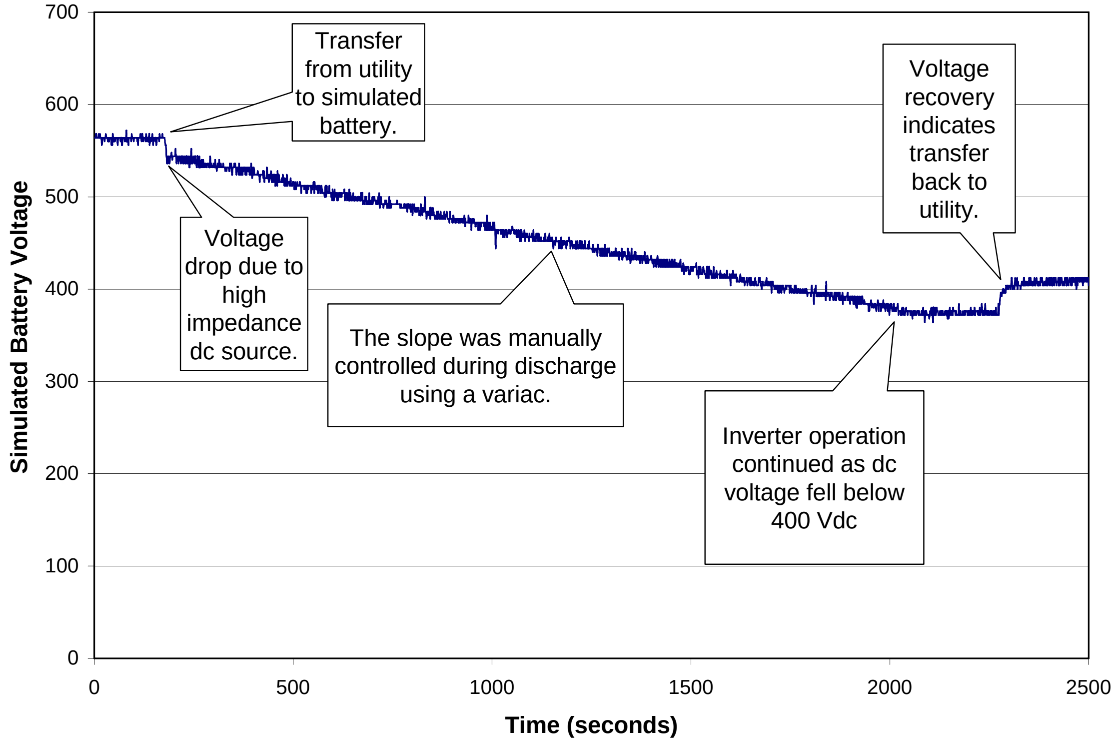

Figure 2-5
Plot of DC Battery Voltage as Changes From Approximately 580 Vdc to Less Than 400 Vdc

3
APPLICATION OF THE AVC-STORE

Market

VECTEK offers several products for partial or whole-plant protection. Customers can purchase just the AVC, the AVC-Deepsag for protection against voltage sags below 50% using electrolytic capacitors for short-term energy storage, and the AVC-Store for runtimes from cycles to minutes using a variety of energy-storage technologies, depending on the customer's preference.

According to market information provided by VECTEK, one trend in power conditioning is the customer's recognition that whole-plant protection can be cost-effective. It is not enough that equipment meet the requirements of SEMI F47[2]. Customers seem to be asking themselves, "Why risk a process shutdown due to an unprotected pump or microcontroller that somehow slipped through the system and is susceptible to a sag in voltage?" Thus, there is a market demand for MW-class systems to provide voltage-sag and short-term outage protection to whole facilities. To penetrate this market, VECTEK has designed a flexible, modular product that is easily customized to meet the personalization required for each large-scale application. In fact, as of November 2006, VECTEK claims to have has supplied over 150 MW of voltage conditioners to semiconductors facilities in Asia and North America and expects greater than 100% growth over the next year. VECTEK estimates the market for whole-plant protection to be in excess of one billion dollars within five years.

In addition to increased uptime, a key market driver is the realization that there exists a relationship between voltage sags and reliability of connected equipment. VECTEK reports that apart from the savings associated with improved production, one of its customers has reported that its electrical maintenance costs have been greatly reduced due to not having to replace circuit boards and repair drives as previously required [1]. This anecdotal evidence follows research by Divan, Bendre, and Johan [6], who report that inrush current occurring as the utility voltage recovers from a sag in voltage can have a negative impact on the input circuits within power supplies. In some cases, this inrush may cause immediate damage, but in others, it may create significant stress such that the lifetime of components is degraded. Moreover, these researchers report that larger plants and buildings with connected loads of 1 MW to 30 MW tend to have stiffer buses (lower source impedance), resulting in even higher current surges, which

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[2] The SEMI F47 *Specification for Semiconductor Processing Equipment Voltage Sag Immunity* document defines the threshold at which a semiconductor tool must operate without interruption (per SEMI E10) and also provides a target for the facility and utility systems. Recognizing that semiconductor factories require high levels of power quality due to the sensitivity of equipment and process controls and that semiconductor processing equipment is especially vulnerable to voltage sags, this document defines the voltage-sag ride-through capability required for semiconductor processing, metrology, and automated test equipment.

implies a greater susceptibility to premature failure of connected devices as a result of voltage sags.

There are other products on the market that compete with or at the least overlap in some areas the markets served by VECTEK. In specific, customers can choose a traditional online UPS, an offline UPS, or a rotary UPS (flywheel-based). Each has specific advantages and disadvantages, requiring the user to study their particular applications and weigh the benefits of each technology. To aid in the analysis, an attempt was made to create a generic comparison to assist the reader in understanding, at least on a high level, the differences and advantages of these complex technologies. The comparison considers features, efficiency, and footprint.

Table 3-1 compares the key features of options for whole-plant protection. The online UPS is the only option that provides runtime in excess of thirty seconds. The AVC devices and the online UPSs provide output regulation, but most UPSs regulate only for balanced loads, while the AVC will correct for voltage unbalance. The offline UPS does not provide any voltage regulation. The AVC provides for active harmonic correction, while the other technologies do not. Finally, the AVC provides protection from voltage sags, while the other technologies do not (unless the sag is of sufficient depth to active a transfer to stored energy).

Table 3-1
Comparison of Features for Technologies Used to Provide Whole-Plant Protection

Feature	AVC	AVC-Deepsag	AVC-Store[3]	Offline Static UPS	Online[4] Static UPS	Rotary UPS[5]
Sag Ride-Through (sec)	30	30	30	30	300+	15
Outage Ride-Through (sec)	-	-	up to 30	30	300+	15
Protection Depth (% of Nominal)	15%	0% (1-Phase)	0%	0%	0%	0%
Output Voltage Regulation	+/- 1% continuous for 90% to 110% voltage	+/- 1% continuous for 90% to 110% voltage	+/- 1% continuous for 90% to 110% voltage	No	+/-1% for balanced loads	1% for steady state
Works with Regenerating Loads	Yes	Yes	Yes	No	No	No
Active Harmonic Correction	Yes	Yes	Yes	No	No	No
Efficiency (100% load)	99.0%	98.9%	98.8%	98.0%	92.0%	93.5%

[3] 30 seconds of storage.

[4] Minimum battery time.

[5] 15 seconds of storage at full load.

Table 3-2 compares the technologies for whole-plant protection in terms of efficiency and provides a relative advantage in operating cost based on a conservatively estimated kWh cost of five cents. For installation inside the plant, the savings are even greater in applications where the cost associated with cooling can be included.

Table 3-2
Comparison of Operating Costs for Technologies Used to Provide Whole-Plant Protection

Technology	AVC	AVC-Deepsag	AVC-Store	Offline Static UPS	Online Static UPS	Rotary UPS
Efficiency at 100% Load Factor	99.0%	98.9%	98.8%	98.0%	92.0%	93.5%
Yearly Operation Cost at 5 cents/kWh, 1 MW System	$442,424	$442,872	$443,544	$446,939	$476,087	$465,957
AVC-Store Advantage (per Year)	N/A	N/A	$0	$3,394	$32,543	$22,413

In addition to features and efficiency, there is a difference among whole-plant technologies in terms of footprint, which is important when you consider that often entire rooms are needed to house the equipment. A smaller footprint can represent a significant cost savings. Table 3-3 clearly indicates a significant savings in required space for installation.

Table 3-3
Comparison of Footprint in Square Feet (ft^2) for Technologies Used to Provide Whole-Plant Protection (Does Not Include Clearance)

Ratings (kVA)	AVC2	AVC-Deepsag	AVC-Store	Offline Static UPS	Online Static UPS	Rotary UPS
200	7.1	7.1	17.1	35	22.5	15.3
300	7.1	7.1	17.1	35	22.5	38.5
400	7.1	14.2	24.2	55.4	34.4	38.5
600	14.2	14.2	24.2	55.4	35.8	50
800	14.2	14.2	34.2	89.3	45.8	84.2
1,000	21.3	21.3	41.3	116	46.8	84.2
1,200	21.3	28.4	48.4	116	60	108
1,600	21.3	28.4	58.4	179.5	91.2	180
2,000	28.4	35.5	82.6	232	110	180
2,400	28.4	42.6	103.7	232	125	220

Production Schedule and Cost

As of November 2006, VECTEK has shipped one second-generation AVC to a regenerating harbor crane in Asia for installation in December 2006. Full production for the AVC and AVC-Deepsag will begin January 1st 2007 with full production for the AVC-Store to follow in April of 2007.

Cost for the various systems depends on the amount of protection required. Given the targeted applications, the AVC products are typically personalized. A fair degree of effort both on the part of the customer and manufacturer are required to ensure a successful installation. For example, a key decision point is the level of protection required. VECTEK offers systems with a range of protection in terms of the depth of sag that is corrected. They do this because system cost is closely associated with sag depth. The series injection transformer and power electronics are not sized for the load but for the difference between utility voltage and required output voltage. In the case of a one megawatt load with protection to 70%, the system is designed for 30% of one megawatt. All things being equal, a system designed for 30% will cost less than a system designed for a sag in voltage to 50%, which must include components designed for 50% of the load. Additionally, the voltage at which the system operates is important because it costs more to provide higher current. So, a system operating at 480 Vac will typically cost less than one operating at 208 Vac. The best metric to use for comparison with other technologies is return on investment, which, VECTEK is quick to note, is usually less than two years and often less than one.

4
SUMMARY

This report describes and documents the design performance, and application of an active voltage conditioner (AVC) with energy storage (AVC-Store). Comprised of a novel power electronics module, the system is organized to mitigate voltage sags, phase shifts, and outages.

The AVC-Store is manufactured by VECTEK of Napier New Zealand, whose principal area of expertise is in the application of microelectronic control techniques to three-phase power equipment and systems. Their core competency encompasses the application of high-power electronic converters, IGBT inverters, SCR transfer switches, embedded control software, and high-speed, broadband control. As of November 2006, VECTEK claims to have has supplied over 150 MW of voltage conditioners to semiconductor facilities in Asia and North America and expects greater than 100% growth over the next year. VECTEK estimates the market for whole-plant protection to be in excess of one billion dollars within five years.

The AVC-Store is a second-generation technology with main subsystems consisting of a static switch, parallel inverter, AVC, and energy storage to provide protection from power quality events such as voltage sags and short-term interruptions. The AVC is comprised of a series transformer with high-speed inverter to either buck or boost the voltage during a swell or sag in voltage. In addition to sag correction, the AVC corrects for phase shift by continuously monitoring the three-phase voltages on the utility supply and comparing them with digitally-balanced sinusoidal-reference waveforms that are phase-locked to the utility supply.

The AVC uses a voltage source inverter called the Vo2 to convert the dc voltage produced by the energy storage to ac voltage used by the load. The inverter makes use of a proprietary high-speed serial backplane to centralize control for the power switches. AVC-Store has flexibility in terms of input dc voltage that allows for simple custom configuration of the AVC-Store for one or more energy-storage technologies.

The AVC-Store monitors all three input phases. If a voltage sag is within the correction window of the AVC, typically down to 70% for a three-phase voltage sag, the static switch will stay connected to the utility mains. However, if the voltage on one or more phases sags below 70%, the system will initiate a transfer from utility voltage to the stored energy.

The operation of the AVC-Store was witnessed at the VECTEK facility using two different systems: a prototype AVC-Store that consisted of a static switch, parallel-connected inverter, batteries, and AVC, and a second system that consisted only of the next-generation AVC that made use of the Vo2 module (without static switch and energy storage). The results of the testing indicate good performance.

VECTEK offers systems with a range of protection in terms of the depth of sag that is corrected because system cost is closely associated with sag depth. The reason for this is that the series injection transformer and power electronics are not sized for the load but for the difference between utility voltage and required output voltage. Additionally, the voltage at which the system operates is important because it costs more to provide higher current. VECTEK is quick to note that once the cost of power quality is determined, the return on investment is typically acceptable to customers and reports some installations with a return on investment of less than one year.

5
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Weblinks

VECTEK website

http://www.VECTEK .com

Omniverter website

http://www.omniverter.com/

Divan Article

http://powerelectronics.com/power_systems/safety_environmental_approvals/power_filling_gaps_surge/

A
PRELIMINARY DATASHEET

ACTIVE VOLTAGE CONDITIONER
AVC Store

Electrical Specifications: AVC Store

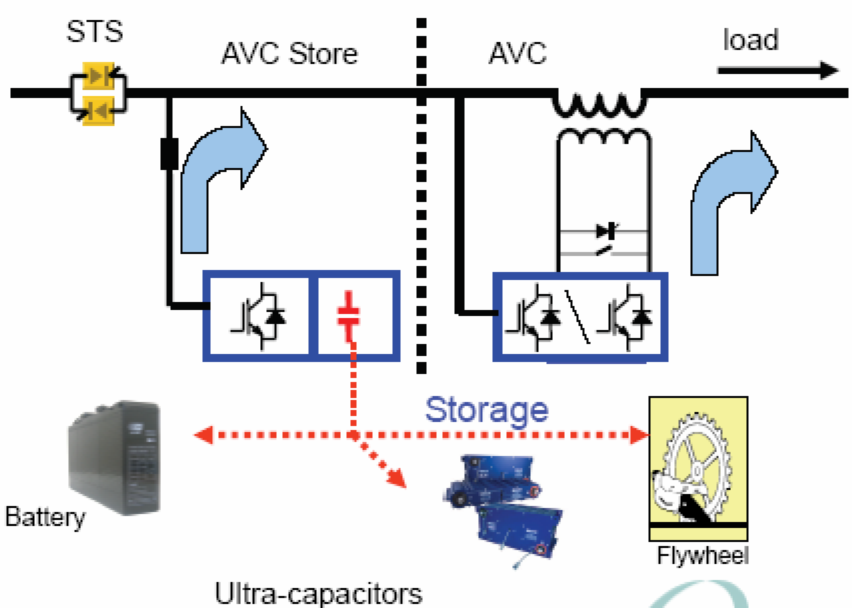
Description

The "AVC Store" is an add on option for the Vectek Active Voltage Conditioner (AVC) products that utilize energy storage to allow the system to ride through momentary outages of up to 30 seconds duration. The ride through time will be dependent on the unit loading and the capacity of the storage system connected which can be batteries, super-capacitors or a flywheel system.

The system is designed to connect on the utility side of a standard Vectek AVC. During normal operation the static switch is closed and power is conditioned by the load side connected AVC. Should the utility supply fail or the input voltage drop below the regulating capacity of the AVC the static switch will be opened and energy for the critical load supplied from the storage system. Should the utility voltage return before the storage is exhausted the system will resynchronize to the utility supply, close the series static switch and return to normal operation.

The operation of the system is specifically designed to meet the demanding requirements of industrial load protection where the following features are particularly important:

- Extremely high electrical efficiency meaning much lower ongoing cost of ownership than traditional UPS solutions and much less heat needs to be removed from the room in which the AVC is located.
- High reliability due to the three levels of redundancy offered in the AVC design.
- High levels of fault clearing capacity (typically 20 time's current short term) to allow for the discrimination of protection systems.
- Ability to cope with industrial loads such as motor drives which are high in harmonic draw and also loads that may regenerate power.



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Load Capacity	
Capacity	200 – 2400kVA; to 50MVA as custom design
Displacement Power Factor of connected load	0 lagging to 0.9 leading
Crest Factor for rated kVA	2 at 100% of rated load
Overload capability (>90% supply voltage)	150%, 30 seconds, once per 500s
Input Supply	
Nominal Supply Voltage (according to model)	480V, 600V 50/60Hz 400V 50 Hz (380/400/415V) 208V 50/60Hz Voltages up to 38kV available as custom applications
Power system type	3 phase, centre ground referenced
Supply voltage category	Level III transient voltage capability
Fault capacity	refer model tables
Required Transformer Supply Bus-Bar size rating	< 80°C operating temperature at rated load
Operating voltage range for regulation and sag correction	
Maximum Supply Voltage	110% of nominal supply voltage
Minimum 3ϕ Supply Voltage	80% without using storage
Output Supply	
Nominal output Voltage (V)	set to match nominal supply voltage
3ϕ voltage regulation range	+/- 10% continuous
3ϕ voltage regulation accuracy	+/- 2%
3ϕ balanced sag correction ability	
- 15% model	+15% /-10% min. 10s
- 20% model	+20% /-10% min. 10s
Sag correction accuracy (within specified range)	+/- 2%
Sag correction response	
- Initial	< 250us
- complete	< 0.5 cycle
Equivalent series impedance (operating)	< 4% typical
Outage response	< 0.25 cycle for non-regenerating loads
Efficiency of system	0.98 to 0.99 (refer model tables)
BYPASS	
Capacity	100% model rating (kVA)
Maximum overload capacity (in bypass):	
- 10 minutes	125%
- 1 minute	150%
- 1s	500%
- 200 milliseconds	2000%

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Transfer time		
	- Inverter to bypass	< 0.5 ms
Equivalent series impedance (bypass)		< 2.5% typical

STORAGE

Maximum Float Voltage	750 VDC
Charger	to suit storage system
Autonomy	storage system dependent to 30 sec

INTERFACE

Access protocol	Ethernet connectivity; Modbus-RTU, dry contacts

ENVIRONMENTAL

Enclosure environmental rating		NEMA 1, IP20
Pollution degree rating		2
Minimum operating temperature		0 °C
Maximum operating temperature		40°C
Temperature derating		above 40 °C derate at 2% per °C to a maximum of 50 °C
Capacity derating with elevation		-1.2% every 100m above 1000m
Cooling		
	- Inverter	forced ventilation
	- transformer	fan assisted ventilation
Humidity		< 95%, non-condensing
EMC emissions		CISPR 22 level G
Noise		65dBA

Standards

Designed to :
UL /CSA
EN50178
C-Tick
CISPR22

All specifications are subject to change without notice.

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