Impact of Voltage Sag Correction in Critical Manufacturing Applications

Dr. Deepak Divan Robert Schneider Dr. William Brumsickle
Dave Trungale Trevor Grant

SoftSwitching Technologies
8155 Forsythia Street, Middleton, WI 53562 – www.softswitch.com
Phone: 608-662-7200 – Fax: 608-662-7300 – info@softswitch.com

ABSTRACT

The dominant power quality problems in industrial manufacturing applications are short duration voltage sags and momentary interruptions. For 'normal' distribution grid customers, the EPRI Distribution Power Quality Study showed the vast majority of power line disturbances to be of short duration. For customers connected to 'premium' grids – those with dual independent distribution feeds, connection to transmission grids, or highly meshed grids – shorts duration voltage sags are essentially 100% of the power disturbances they experience. Power quality solutions that protect against all short duration power line disturbances remedy virtually 100% of all the events experienced by those customers who have the highest cost of downtime: the 'premium' grid customers.

With over 500 Dynamic Sag Corrector™ (or DySC®—pronounced 'disk') solutions protecting critical manufacturing processes, there is now a wealth of information on the efficacy and impact of such devices. This paper presents case studies of several applications, including the automotive, semiconductor and general manufacturing sectors, for customers on both 'normal' and 'premium' grids. The location and rating of the unit has a big impact on the economic returns, and specific examples of how the optimal ratings were chosen are discussed. The pros and cons of 'facility wide' versus 'point of use' protection are also discussed. Finally, an approach for modeling the ROI for manufacturing processes is presented.

INTRODUCTION

Power-related problems—both power reliability and power quality events—cost U.S. industry $150 to $190 billion annually in lost productivity and downtime, according to independent EPRI and DOE study estimates. Results of the EPRI Distribution Power Quality Study refocused the entire power technology sector by showing that only 3% of events experienced by distribution grid industrial customers were outages, the balance were short duration disturbances. The normally 'reliable' distribution-level utility service does not provide the high quality of power delivery needed by many industrial and commercial electricity users.

The notion of *high 9's* power for critical manufacturing processes is receiving increasing attention. The distinction between power reliability (the absence of utility voltage) and power quality (the corruption of the 'ideal' utility voltage) problems is becoming better understood. High-value process industries, such as semiconductor and automotive manufacturers, are often served by a *premium grid*, connected to dual independent distribution grids, and typically experience incoming power reliability of seven 9's (99.99999% availability). Nevertheless, if their process can be interrupted by a ¼ second voltage sag, it is very likely that the end-customer will have experienced only two or three 9's power: 99% to 99.9% up time (see Table 1). Because long outages are very rare, particularly with premium-grid connections, industrial manufacturing applications typically only require ride-through for short duration power disturbances, such as voltage sags, to achieve up to nine 9's.

SoftSwitching Technologies introduced the DySC (Dynamic Sag Corrector) product line in 1999, specifically targeting protection of industrial loads against voltage sags and momentary interruptions. Now with many hundreds of units in the field, our experience has verified the effectiveness of such 'short event' solutions for keeping high-value critical manufacturing processes running, including automotive, semiconductors, plastics, fiber-optic cable, paper, steel, cement, and food and beverage processing.

In this paper we summarize some significant insights gained from this real-world experience across diverse industries—experience that both validates and enhances the accepted interpretations of the research studies completed to date. We present several illustrative case studies that highlight the problems faced in effectively addressing power 'events' on both 'normal' and 'premium' grids. We also include examples of how to select optimal sag corrector unit ratings, and contrast facility-wide protection with point-of-use protection.

POINT OF USE VERSUS FACILITY WIDE PROTECTION

One important consideration with a major impact on ROI is the issue of the 'best' approach to protect a sensitive process or load. Two distinct approaches have emerged:

- facility-wide protection, typically medium voltage devices rated at 2-10 megawatts (examples include DVR and SMES)
- point-of-use protection, typically 120-480 volt devices rated at 250 watts to 3,000 kilowatts (examples include the DySC and ESP)

The use of facility-wide protection seems attractive at first glance: the entire plant is protected. However, as only 20-30% of a plant's load is likely to be sensitive, facility wide protection consistently results in a more expensive solution than is truly needed. Further, the medium voltage systems are custom, requiring long lead times. Finally, these units cannot protect the sensitive loads from sags caused by faults in other non-critical areas inside the facility. With point of use protection, the customer's can typically choose a unit rating that optimally matches their sensitive load. The ability to stage the deployment over several years, allows prioritization of limited budget dollars.

Choosing among the MINIDySC and PRODySC family of products, one can select the optimal protection to be deployed in a given facility and application. The MINIDySC™ solutions are available for single phase loads rated from 250 watts to 20,000 watts. For three phase configurations, the PRODySC® is rated from 9 kilowatts to 330 kilowatts in single modules, and paralleled module systems can realize up to 3,000 kilowatts. It is interesting to note that there is no single right solution, and that the choice of the correct solution can involve many factors. The DySC product family is represented in Figure 1.

Clearly, in a green-field installation where the equipment or process designer has full design flexibility and authority, one could in principle, design the overall equipment or process to be fully immune to externally-caused voltage sags and power disturbances of all types. However, as there is no guiding standard on equipment and components for voltage sag susceptibility, we see very wide variance in susceptibility, often even for similar products from the same manufacturer. For systems and equipment such as semiconductor tools—those that are assembled from readily available sub-systems and components—it is almost impossible to predict a priori what the overall sensitivity will be to voltage sags.

In such a case, one approach is to perform detailed tests and engineering analysis, painstakingly identifying all sensitive components and replacing them or protecting them with smaller MINIDySC or PRODySC type of devices. The alternative is to protect the entire machine or large sub-systems with larger PRODySC devices. Both approaches have been followed, as will be evident from the case studies that follow.

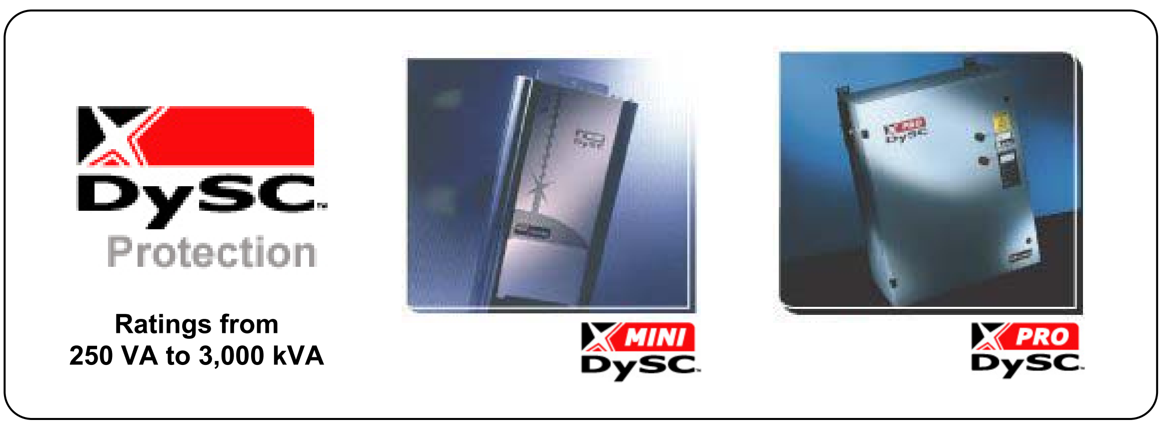

Figure 1: *DySC® product family and ratings.*

DEMONSTRATING PERFORMANCE IMPROVEMENTS

While generally validating the EPRI-DPQ Study statistics, our field experience has also identified an important exception. In particular, we see a clear discrepancy between events experienced by customers connected to the 'normal distribution' utility grid (the focus of the EPRI-DPQ Study), and 'premium' grid customers. Premium grid customers are either connected to dual independent distribution feeds with a built in automatic transfer switch, or connected to the primary grid at >230 kV, or connected to highly meshed grids.

Demonstrating their dependence on high-reliability power, most premium grid customers have monitored and collected data on power events over many years. The customers' data show that the premium grid has virtually eliminated unplanned power outages: generally, at least ten years between outages. Monitoring of normal utility grid customers, on the other hand, largely supports the EPRI-DPQ Study result model.

With this in mind, we can now estimate the reliability improvement a customer will experience by adding DySC protection and also explain an all-too-common 'disconnect' between utilities and their industrial customers.

Table 1 summarizes the contrasting power event profiles experienced by a normal utility grid customer (the EPRI-DPQ Study profile) and a premium grid customer. On the typical normal grid, a customer is subjected to 2,107 seconds in a year when the utility voltage is out of specification. In terms of the 'level of 9's' gauge, the apparent utility reliability is approximately four-9's. The utility's perspective is that it has provided highly reliable service: using traditional metrics, only the two sustained interruptions are considered in measuring reliability. But what is the customer's view? If their processes have been interrupted for an hour every time there is a power event, they will have experienced 25 hours of downtime per year, or a reliability level of only two 9's. This scenario represents a major discrepancy between the utility and customer perspectives—a 'disconnect' that often impedes the selection of optimal power solutions.

For premium utility customers, the contrast is yet more stark: With only ten short duration events occurring in an average year and outages virtually eliminated, conventional metrics indicate seven 9's and no interruptions—from the utility's perspective. Nevertheless, the sensitive customer would have experienced (based on 1 hour downtime per event) ten hours of process interruption, corresponding to a level of only two 9's—in spite of a significantly higher cost of service.

The DySC, which offers up to 2 seconds of correction for 50% voltage sags and ride-through on an interruption for 3 to 12 cycles, can effectively close this gap. The bottom of Table 1 shows the improvement available to both the normal and premium grid utility customer through application of a device such as a DySC. While the normal grid customer is expected to see a full '9' of improvement, the impact on premium grid utility customers is the most dramatic: The sag corrector addresses all the residual non-outage events, virtually eliminating power-related downtime. The premium grid customers' reliability level has been improved from two 9's to over seven 9's, matching the reliability of the primary grid itself.

NORMALGRID				PREMIUM GRID			
Normal Utility Events	Utility Reliability Level	Process Uptime 1 Hr Downtime per Event	Typical Applications	Premium Utility Events	Utility Reliability Level	Process Uptime 1 Hr Downtime per Event	Typical Applications
25 events/yr: 22 at ¼ s, 1at 2 s, 1 at 5 min, 1 at ½ hour	2107 seconds total/yr, 99.99%, 4-nines	25 Hrs total downtime/yr, 99%, **2-nines** No protection	Plastics, PCs, Machinery, Textiles, Cell towers, Residential	10 events/ yr, 0.25 s each	2.5 seconds total/yr, 99.99999%, 7-nines	10 Hrs total downtime/yr, 99%, **2-nines** No protection	Semi manuf, Auto manuf, Fiber optic cables, Web farms, Continuous processes
92% Events Protected with a DySC 2 events/yr, 2 hours total downtime/yr, 99.9% Process Uptime **3-nines**				100% Events Protected with a DySC 100% Process Uptime **9-nines**			

Table 1: *Availability vs. Process Uptime in Normal & Premium Grids.*

CASE STUDIES

The real world applications and experiences of actual companies are more illuminating than arguments based on statistics. Here are details from some actual installations.

I. Engines, Inc., a manufacturer of large axles and rotors for railway and other applications located in West Virginia, was experiencing 10-15 sag events annually. This resulted in many hours of downtime, scrapping of large expensive rotors, and delayed shipments. In cooperation with AEP and EPRI, SoftSwitching Technologies installed a 300 kVA PRODySC unit to cover the main production line. According the Engines, Inc. President Carl Grover, " the DySC has virtually eliminated the necessity for reworking damaged materials due to voltage sags."

II. A major fiber-optic cable manufacturer was experiencing 6-10 voltage sags per year. As a premium grid customer, this company had over seven years of power monitoring data, which showed no power interruptions, only voltage sags. One cable finishing process line could realize losses reaching $150,000 - $500,000 per event. Over a dozen PRODySC systems with a cumulative rating of over 3,500 kVA are now protecting a portion of the cable finishing area in this plant. In the first three months of operation two definite, documented 'saves' were recorded. The DySC investment was paid for with the first save.

III. Imperial Sugar in Houston was experiencing voltage sags and momentary interruptions as a result of lightning activity in the region. In cooperation with Reliant Energy, a 300 kVA PRODySC was installed to provide additional backup for the facility's computer and data center. The unit has been operating for over a year and a half, and has recorded a large number of saves. Over a twelve month period, the DySC covered all the events that were recorded by utility monitors.

IV. A manufacturer of large-die plastic extrusion products, in cooperation with EPRI-PEAC, their local utility company, and SoftSwitching Technologies, installed a 300kVA PRODySC unit solution to protect several extrusion lines. Figure 2 shows how the PRODySC unit corrected a deep voltage sag to keep the process running.

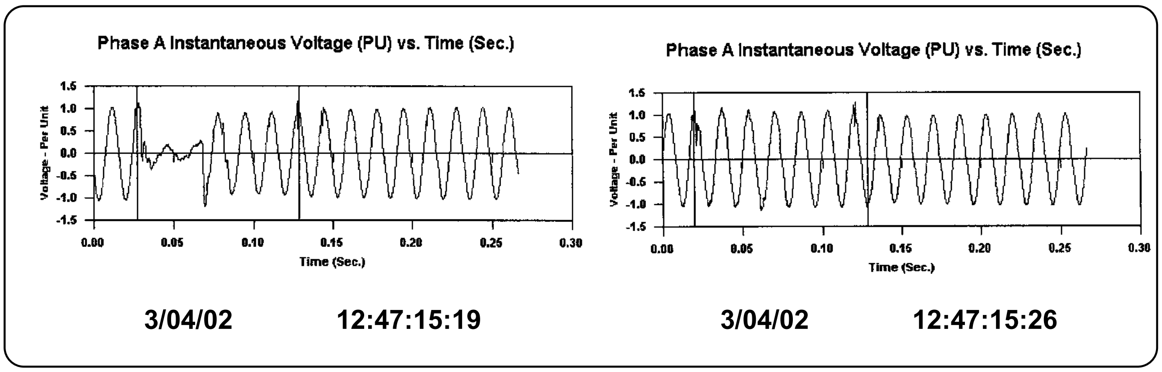

Figure 2. *Typical Event Showing Both Incoming Line Voltage & Corrected Output*

V. A major automotive manufacturer required protection for the distribution bus that supplied one of their body shops, which includes robotic welding, PLC based material handling and ancillary industrial controls. The body shop was a critical production cell because a shutdown of the robots during a body welding operation may cause the whole body to be scrapped. The size of the bus is 1600 A but the actual load at present is less than 1200 A. The customer found it most efficient to cover the whole bus but only to the current level that was presently being used. A modular 1200 A PRODySC system was installed, with expansion capability to 1600 A at a later date. Provisions were also included for future installation of additional capacitive energy storage, if warranted by further monitoring data. The installation has also been equipped with I-Sense™ monitors, one for input voltage and one for output. The system has been operating since May of 2001 and several sag events have been recorded; one event is depicted in Figure 3. The customer reports that for almost all events, the other equipment in the plant shut has down on 'power loss' while the bus protected by the PRODySC kept the body shop up and running.

Figure 3. *Auto. plant data: Input sag voltage and PRODySC corrected output voltage (RMS)*

VI. A major semiconductor manufacturer required sag correction for their photolithography tools. Voltage sags caused shutdowns resulting in scrap material and lost production capacity. This installation was ideal for distributing PRODySCs at the input of each tool. Over ten 42 kVA PRODySCs were installed ahead of respective tools. The DySC units fit nicely into the facility as their small size allowed them to be arranged in accordance with the space limitations of the tool power supply room. This customer has reported several sag events since August of 2001, again resulting in continued operation of the semiconductor tools while other less critical unprotected equipment was shut down.

More generally, the important role of sag correction on improved process reliability has clearly been recognized by the semiconductor fabrication industry—as evidenced by their adoption of voltage sag susceptibility standard SEMI F47. The protection profile of the DySC product family completely overlays that required by SEMIF47—one of the reasons that the DySC has been successful as a drop-in global OEM solution for major tool manufacturers.

CONCLUSIONS

Sag correction devices offer an attractive ROI across a broad spectrum of industries, based on their ability to enable premium grid customers to achieve virtually 100% protection and normal grid customers to add a full '9' to their power reliability. Enabling deployment at the point-of-use provides significant benefit in cost and installation time. While they offer the greatest incremental improvement in process reliability to premium grid customers, sag correction devices such as the DySC provide even normal grid customers with decreased downtime due to power events by more than an order of magnitude. As a result, proven products such as the DySC are uniquely positioned to have a dramatic impact on specific customers, industry sectors, and the overall economy.

REFERENCES

Electric Power Research Institute. "An Assessment of Distribution System Power Quality." TR-106294s-V1-3 Research Projects 3098-01. Palo Alto, Calif., 1996.

Semiconductor Equipment and Materials International (SEMI). Standard SEMI F47-0999. "Provisional Specification for Semiconductor Processing Equipment Voltage Sag Immunity." Mountain View, Calif.