Industrial-Strength Sag Correction

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For manufacturing facilities, power disturbances or outages that halt production translate into billions of dollars of lost revenue every year. Since 1999, SoftSwitching Technologies has offered a line of sag correctors specifically designed to protect industrial loads from voltage sags and momentary interruptions. In this article, we'll describe how sag correctors operate and how they can improve process uptimes. We'll also profile several companies using these devices and offer some time-tested advice on what to consider before implementing power quality solutions.

A major component of many voltage sag correction devices is electrical or mechanical energy storage. During sags or brief interruptions, a power converter draws the stored energy to synthesize normal utility voltage for the protected load. When utility voltage is restored, the load is transferred back to the incoming source. An alternate approach uses a series injection transformer coupled to the line as a means of boosting the incoming sagging utility voltage.

SoftSwitching Technologies' line of DySC™ (pronounced disk) sag correctors employs a transformerless-series, voltage-injection device that boosts the incoming line voltage up to 100%, even for symmetrical 3-phase voltage sags (see **Fig. 1**). Instead of completely isolating the normal supply under sag conditions, the DySC takes the remaining voltage and boosts it to its pre-sag value. In this way, the device provides sag protection without the additional cost or complexity of electrical or mechanical energy storage. The DySC also protects the load for short momentary interruptions—up to 3 cycles at rated kVA loads. Additional capacitive energy storage can be provided to increase the ride-through for momentary interruptions up to 12 cycles.

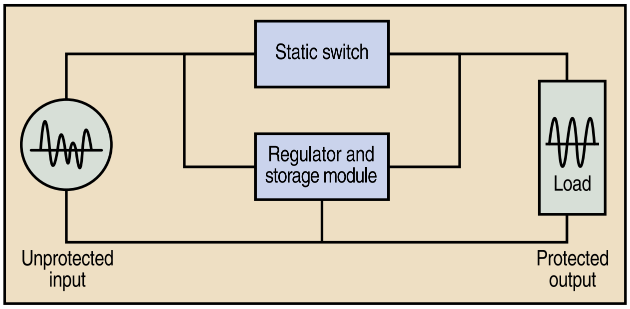

Fig. 1. *A line drawing of a Dynamic Sag Corrector (DySC™).*

Improving Customer Uptime

To understand the benefit of sag correctors, it's helpful to compare the reliability levels of normal- and premium-utility grid connections. Many high-value process industries (e.g., semiconductor, automotive, and fiber-optic cable manufacturers) are connected to premium grids. Premium-grid customers are connected to one of the following:

- Dual independent distribution feeds with built-in automatic transfer switches
- The transmission grid at greater than 230kV
- Highly meshed grids, such as those in Singapore or Manhattan

The **table** on page 28 presents a typical power-event profile that may be experienced by normal- and premium-grid customers. As you can see, the utility reliability level for normal utility events is 99.99% (4 nines, or 2107 sec per year), and the level for premium events is 99.99999% (7 nines, or 2.5 sec per year). This may constitute highly reliable service from the utility's perspective, but customers that experience 10 to 25 hours of downtime annually may have a different outlook. As the **table** illustrates, premium-grid customers that experience 1 hour of downtime per event

Event	Typical Applications	Events Per Year	Utility Reliability Level	Customer Uptime Per Year (based on 1 hour for each downtime event)	Events and Customer Uptime Per Year With Sag Corrector
Normal utility	Plastics, PCs, machinery, textiles, cell towers, and residential	25 (2 interruptions and 23 sags totaling 2,107 sec)	99.99% (4 nines)	99% (2 nines)	2 events per year totaling 2 hours, 99.9% (3 nines)
Premium utility	Semiconductor, automotive, and fiber-optic cable manufacturers; Web farms; and other continuous-process facilities	10 (10 sags totaling 2.5 sec)	99.99999% (7 nines)	99% (2 nines)	Zero events per year, 100% (9 nines)

Table. *Comparison of normal and premium utility events.*

only achieve 99% (2 nines) of power reliability—the same as normal-grid customers—despite a significantly higher cost of service.

The **table** also shows how employing a sag corrector can improve process uptimes for normal- and premium-grid customers. Sag correction devices offer up to 2 sec of correction for 50% voltage sags and ride-through on interruptions lasting 3 to 12 cycles. For normal-grid customers, sag correctors reduce downtime by more than an order of magnitude—a significant improvement.

Premium-grid customers experience the greatest incremental improvement in process reliability. In those cases, sag correctors address all events, eliminating power-related downtime.

Case Studies

Engines Inc., a West Virginia manufacturer of large axles and rotors, found its facility succumbing to 10 to 15 sag-related shutdowns annually. This resulted in many downtime hours, scrapped rotors, and delayed shipments. In cooperation with AEP and EPRI, SoftSwitching Technologies installed a 300kVA PRODySC™ to cover the main production line. A typical event showing the incoming line voltage and the corrected output is shown in **Fig. 2**, on page 29. In the fifteen months the unit has operated, facility personnel have not had to rework damaged materials because of voltage-sag problems.

In another case, a major fiber-optic cable manufacturer's

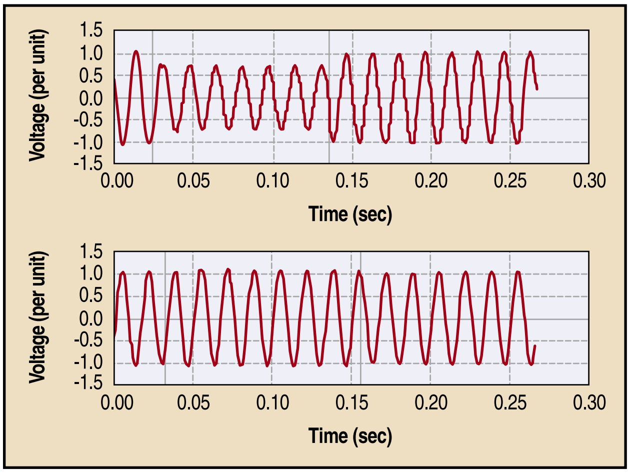

Fig. 2. *A typical event showing incoming line voltage and the corrected output at Engines Inc.*

facility was experiencing six to 10 voltage sags per year. This premium-grid customer had accumulated more than seven years of power monitoring data, which showed no power interruptions—only voltage sags. The most sensitive high-value process was a cable finishing line. If that line went down, losses could cost $150,000 to $500,000 per event. To protect a portion of the cable finishing area, engineers installed more than one dozen PRODySCs with a cumulative rating exceeding 3500kVA. During eighteen months of operation, more than a dozen saves have been recorded and documented. As with many high-value processes, the sag corrector paid for itself the first time it prevented a shutdown.

The last case study involves Imperial Sugar Corp. in Houston. Its facility began experiencing voltage sags and momentary interruptions because of lightning activity in the region. In cooperation with Reliant Energy, engineers installed a 300kVA PRODySC to provide additional backup for the facility's computer/data center. After one year of operation, more than 30 saves have been recorded. **Fig. 3**, on page 30, shows a magnitude-duration plot of events experienced over a twelve-month period, indicating that the sag corrector covered all of the recorded events.

All of the DySC devices installed at these facilities offer protection profiles that meet the requirements set forth in SEMI F47, a standard designed to protect semiconductor fabrication equipment from power quality events. This feature is illustrated in **Fig. 4**, on page 30.

Other Considerations

As the previous case studies demonstrate, each company's situation is unique. Deciding which solutions will best address your power quality problems depends on a variety of factors. Our experience over the years has led us to develop a list of key issues for end users to consider before finalizing their plans.

Application. Deciding whether it is better to apply protection at the substation level or at the machine's location

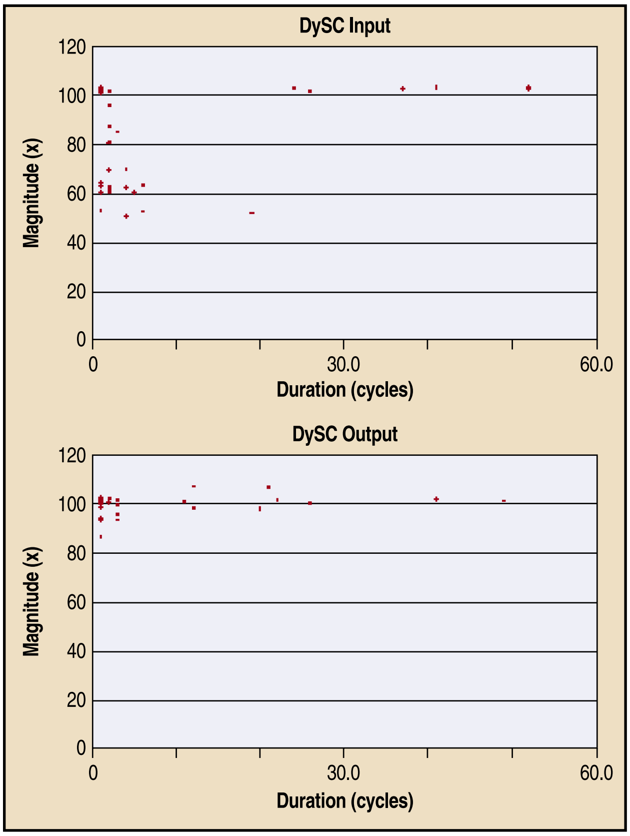

Fig. 3. *Magnitude and duration plots of events experienced over a twelve-month period at Imperial Sugar Corp.*

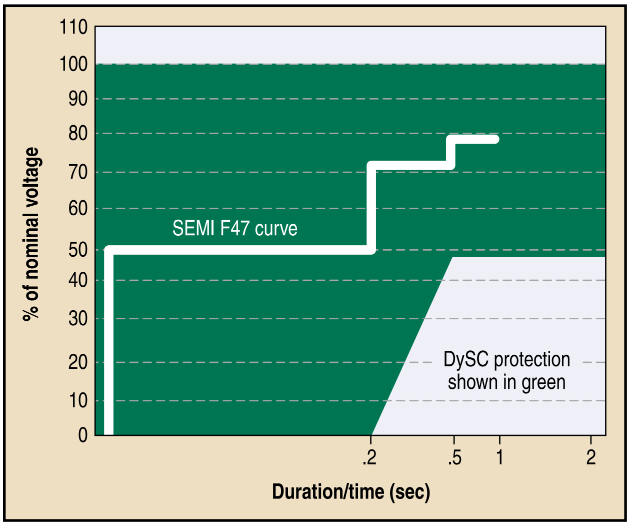

Fig. 4. *The DySC protection curve compared to the SEMI F47 curve.*

can be tricky. Typically, loads are not partitioned by sag susceptibility, and sensitive loads tend to be only 20% to 30% of the total plant load. Protecting all loads thus implies a threefold to fivefold increase in system cost. This must be measured against the increased flexibility provided by centralizing power protection in plant operations. Equipment with modular upgradeable designs and incremental ratings helps tailor solutions to fit your needs.

Dynamic loads. These include phase-controlled rectifiers in DC drives and motor loads, and negative impedance characteristics in all power electronic loads. Dynamic loads can be problematic for protection devices, such as continuously variable transmissions (CVTs) and uninterruptible power supplies, because they require special control techniques that translate into additional time and money. This serves to explain why existing power quality solutions have limited penetration on the plant floor.

Financial aspects. It's important to understand the costs associated with power quality events and then use data to demonstrate the relative cost justification for various solutions. Typically, company decision makers are most receptive to paying for solutions during the six-week period following a power disturbance event. Once this window of opportunity passes, the willingness to fund a solution diminishes until the next significant event.

Also, keep in mind that an engineering design that protects against all possible power events means expensive solutions. Statistically speaking, it is more cost-effective to provide protection against 90% to 99% of events, as opposed to protecting against every conceivable event that can occur in principle. When dealing with company decision makers, make sure they understand the tradeoff between cost and protection.

Grounding schemes. These can often cause interactions, so sufficient knowledge of grounding methods is crucial.

Icecube relays. These are the most sensitive elements in typical industrial machines and control panels. Response times of less than 1 ms and special algorithms are required to prevent load dropouts.

Other equipment. Machines can trip on even the smallest voltage bump if equipment, such as adjustable-speed drives, are used without input line reactors.

Now, more than ever, facilities need 100% uptime to meet the demands of the business world. Manufacturing companies and processing plants of all types can benefit from sag correction devices. Sag correctors help premium-grid customers achieve 100% protection and normal-grid customers to add a full 9 to their power reliability. These devices are part of a market that will continue to broaden and deepen, creating new economic opportunities for all players in the power quality field. PQ

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