PRECICON

Technical White Paper

Strategic Mitigation of Voltage Dips in Semiconductor Manufacturing via Dynamic Sag Correction (DYSC)

By Colin Koh
Principal Consultant LKH Precicon

sales@precicon.com.sg www.precicon.com.sg (65) 6672 9229

Contextualising Voltage Dip in High-Precision Environments

Analytical Introduction

In the semiconductor industry, power quality is the silent determinant of operational profitability. While a total blackout is a rare and obvious failure, voltage dips—momentary reductions in voltage magnitude—represent a more insidious strategic risk. For high-precision manufacturing, even a sub-cycle disturbance can trigger a cascade of tool failures, resulting in ruined wafers, lost production hours, and the potential for long-term equipment degradation. From a strategic standpoint, managing these dips is not merely an engineering task but a requirement for business continuity and regulatory compliance.

Foundational Definitions and Causes

Per European Standard EN50160, a voltage dip is defined as a sudden reduction in voltage of more than 10%, lasting between 10 milliseconds and 1 minute. These disturbances are rarely caused by the utility's intent; rather, they are driven by equipment failures within the grid, damage to underground cables from third-party earthworks, or faults within neighbouring industrial installations. Because modern power grids are highly interconnected, a fault in one segment can propagate across the network, manifesting as a dip for facilities miles away.

The Inevitability Factor and Regulatory Risk

Stakeholders must recognize that voltage disturbances are an unavoidable by-product of a large-scale power network. Total elimination is technically impossible; therefore, resilience is a collaborative mandate between the Energy Market Authority (EMA), SP PowerAssets (SPPA), and the customer. In Singapore, the regulatory stakes are particularly high: under EMA policies (Section 2.1.2), any customer whose installation causes three voltage dips within a 24-month period is mandated to conduct an independent audit and implement corrective actions. Failure to manage internal power quality can thus lead to significant regulatory scrutiny and potential licensing risks for electrical supervisors.

The Role of Precision Power Quality (PQ) Monitoring

Strategic decision-making requires empirical evidence. Without high-fidelity PQ monitoring, facility owners cannot differentiate between grid-side faults and internal equipment malfunctions. This data is essential not only for technical diagnostics but also for justifying the Return on Investment (ROI) for mitigation hardware. A robust Power Quality Monitoring System (PQMS) transforms "nuisance trips" into actionable engineering data.

Monitoring Objectives

Precision monitoring serves three strategic pillars:

1. System Resilience: Continuous evaluation to identify marginal equipment performance and fine-tune ride-through settings.
2. Equipment Characteristic Assessment: Measuring the interplay of harmonics and the I2t characteristics of in-rush currents during motor starts.
3. Energy Management: Utilizing PQ data to optimize consumption and verify the performance of power conditioning equipment.

Technical Selection Criteria

Selecting the correct monitor requires adherence to IEC 61000-4-30. The choice between Class-A and Class-S depends on the criticality of the monitoring point.

Feature	Class-A (High Precision)	Class-S (General Purpose)
Measurement Method	*Uses U_{rms(1/2)} (calculated every half-cycle)*	*Can use U_{rms(1/2)} or U_{rms(1)}*
Accuracy	*0.1% voltage measurement accuracy*	*Lower accuracy requirements*
Sampling Rate	*128 to 256+ samples/cycle*	*Standard sampling rates*
Memory Storage	*High (Requires storage for 1 month of trending + 20+ disturbance waveforms)*	*Variable (Portable units require larger storage for independent investigation)*

Note: For permanent monitors, one month of trending data is the benchmark for effective post-fault analysis.

Analysing Fault Origin

Determining the direction of a fault is the first step in accountability. By evaluating the relationship between voltage magnitude and current:

1. Upstream (Grid) Fault: A voltage dip occurs with no significant change in current magnitude at the intake.
2. Downstream (Customer) Fault: A voltage dip occurs alongside a significant increase in current magnitude, indicating a fault within the plant.

Hierarchical Framework for Voltage Dip Mitigation

Analytical Introduction

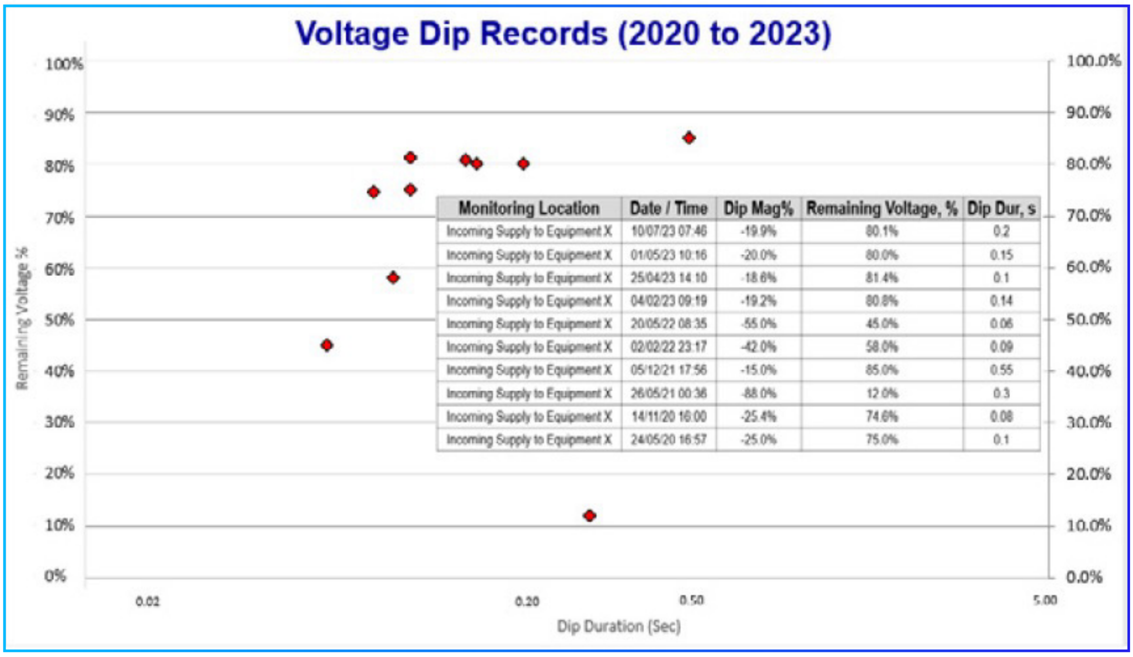
Mitigation strategy is governed by "Risk Appetite"—a tiered approach where protection is applied based on the cost of downtime versus the cost of the solution. This hierarchy ranges from procurement specifications to whole-plant protection.

Option 1: Equipment Specification & Standards

The most cost-effective mitigation occurs at the procurement phase. Standards define the "ride-through" capability of equipment. Based on historical records from 2020–2023, these standards rank in stringency as follows:

1. **SEMI F47:** The baseline for semiconductor tools. Historical data shows it can still fail during severe dips (e.g., those below 50% remaining voltage).
2. **ITIC (CBEMA):** General guidelines for IT and solid-state loads.
3. **IEC 61000-4-34 (Class 3):** Broad EMC framework; still vulnerable to extreme events.
4. **Samsung Power Vaccine**: The gold standard. It requires uninterrupted operation through a 100% dip for 1.0 second.

The Strategic Reality: Historical analysis of incident records by SPGroup's Voltage Dip Management Report shows a severe dip on May 26, 2021, reached 12% remaining voltage for 0.3 seconds. Only equipment specified to the Samsung Power Vaccine would have survived this event without interruption.



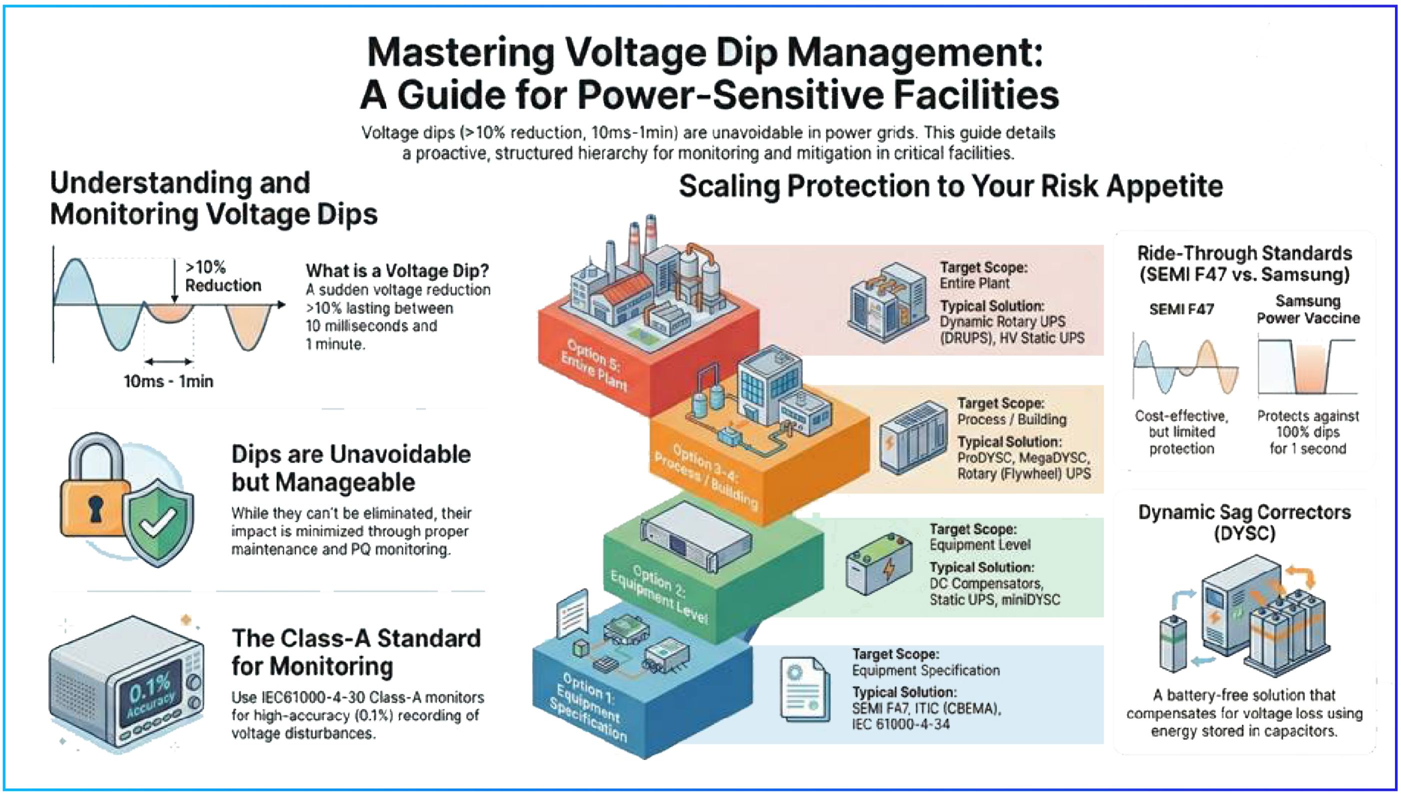
Monitoring Location	Date / Time	Dip Mag%	Remaining Voltage, %	Dip Dur, s
Incoming Supply to Equipment X	10/07/23 07:46	-19.9%	80.1%	0.2
Incoming Supply to Equipment X	01/05/23 10:16	-20.0%	80.0%	0.15
Incoming Supply to Equipment X	25/04/23 14:10	-18.6%	81.4%	0.1
Incoming Supply to Equipment X	04/02/23 09:19	-19.2%	80.8%	0.14
Incoming Supply to Equipment X	20/05/22 08:35	-55.0%	45.0%	0.06
Incoming Supply to Equipment X	02/02/22 23:17	-42.0%	58.0%	0.09
Incoming Supply to Equipment X	05/12/21 17:56	-15.0%	85.0%	0.55
Incoming Supply to Equipment X	26/05/21 00:36	-88.0%	12.0%	0.3
Incoming Supply to Equipment X	14/11/20 16:00	-25.4%	74.6%	0.08
Incoming Supply to Equipment X	24/05/20 16:57	-25.0%	75.0%	0.1

Fig 14: Voltage Dip Records from 2020 to 2023

Source: Voltage Dig Management Guidebook V2.

Implementation Tiers (Options 2–5)

1. **Option 2 (Equipment Level):** Targeted hardening of Variable Speed Drives (VSDs) using DC Compensators.
2. **Option 3 (Process/Line Level):** Strategically placing Dynamic Sag Correctors at the LV sub-switchboard to protect a specific production line.
3. **Option 4 (Building Level):** Protection at the LV main switchboard using Static UPS or MegaDYSC systems.
4. **Option 5 (Plant Level):** Total facility protection using Rotary UPS (RUPS) at the HV (22kV) intake.



Deep-Dive: Dynamic Sag Corrector (DYSC) Technology

Analytical Introduction

The DYSC is a specialized, battery-free solution designed specifically for the semiconductor environment. Unlike traditional UPS systems that prioritise total outages, the DYSC is optimized for high-speed correction of voltage sags without the high maintenance and footprint of lead-acid batteries.

Functional Mechanics

The DYSC employs a high-speed controller and static switch. When a dip is detected, the system switches to a converter in milliseconds. Critically, the DYSC is a series solution that injects energy drawn from unaffected healthy phases or internal capacitors to maintain a stable AC output. This eliminates the need for chemical energy storage for the majority of dip events.

Product Tier Analysis

- **MegaDYSC:** For LV main switchboards, handling loads up to **1.6MVA.**
- **ProDYSC:** Designed for process-line protection, handling up to **140kW.**
- **MiniDYSC:** Single-phase or equipment-level protection, up to **12kW.**

Differentiating Capacities

- **Standard Capacity:** Provides ride-through for 100% dips for up to **50ms.**
- **Extended Capacity:** Increased capacitor storage allows for ride-through of 100% dips for up to **200ms.**

Comparative Analysis: DYSC vs. Alternative Technologies

Strategic selection depends on balancing maintenance, footprint, and the nature of the protection required.

Technology	Primary Advantage	Key Limitation	Maintenance Effort
DC Compensator	*Lowest cost; small footprint*	*Parallel solution; only protects the VSD DC link; no AC-to-AC conversion.*	*Low*
DYSC	*Series solution; protects control electronics & motors; battery-free.*	*Duration limited by capacitor size (max 200ms for 100% dip).*	*Low*
Rotary/Flywheel UPS	*High power capacity; mechanical inertia.*	*High mechanical maintenance; risk of frequency-based trips.*	*High*

The "Frequency Trap" in Mechanical Systems

Mechanical storage systems like Flywheel UPS are vulnerable to frequency thresholds. Case studies show these systems can trip during a minor (3%) voltage dip if the frequency drops below a sensitive threshold (e.g., 49.5Hz). DYSC systems, being static and voltage-threshold focused, avoid this vulnerability, ensuring the plant remains connected to the grid unless a genuine voltage violation occurs.

Operational Case Studies and Strategic Lessons

Case Study 1: Chiller Control Hardening

Industrial chillers often trip not because the motors fail, but because the control relays drop out at a 30% dip. By hardening the control circuit to SEMI F47 standards using small-scale mitigation, the entire system can ride through disturbances for a fraction of the cost of a full-system UPS.

Case Study 2: Exhaust Air Fans (EAF) and the "Flying-Restart"

In clean rooms, zero air pressure is a catastrophic failure. Configuring VSDs for "Flying-Restart"—where the drive catches the spinning motor and accelerates it back to speed—prevents the pressure drop that leads to product scrapping.

Strategic Strategy: Delayed Staggering and the In-Rush Problem

While "Flying-Restart" is effective, an expert strategist must plan for the collective in-rush current. If hundreds of motors attempt to restart simultaneously, the aggregate I2t (energy) can exceed the thermal-magnetic trip settings of upstream breakers. The solution is "Delayed Staggering":

- Critical drives (e.g., EAF) restart immediately.
- Secondary drives are programmed with staggered delays to smooth the current surge and prevent a secondary outage caused by the plant's own protection system.

Conclusion: Engineering Resilience into the Grid and Plant

Voltage dips are a physical reality of the power grid, but their impact on manufacturing yield is a matter of strategic choice. Resilience is achieved through data-driven decisions and a combination of Option 1 (specifications) and active mitigation hardware.

Summary of Recommendations

- **For Semiconductor Owners:** Implement a Plan-Do-Check-Act (PDCA) cycle and identify "Samsung Power Vaccine" as the target for critical tools to survive extreme historical dip events.
- **For M&E Consultants:** Prioritize series-based DYSC solutions over parallel DC compensators for comprehensive process protection (covering both controls and power).
- **For Grid Operators:** Continue online Partial Discharge Monitoring and maintain transparent communication of fault data to assist in customer-side forensics.

By moving from reactive maintenance to a proactive, hierarchical mitigation strategy, semiconductor facilities can achieve the high levels of power "immunity" required for modern competition.

Author : Colin Koh www.linkedin.com/in/colinkoh
Title : Principal Consultant
Company : LKH Precicon Pte Ltd www.precicon.com.sg

For Inquiry contact Product Manager : Mr Derrick Lim
derrick@precicon.com.sg

Background Information

LKH Precicon Pte Ltd ("Precicon") was established in 1985 and is a wholly owned subsidiary of Tai Sin Electric Limited, a company listed on the SGX Mainboard. Precicon specialises in delivering Smart, Secure, and Sustainable Industrial Power Quality (3S+IPQ) solutions to mission-critical industrial environments, including advanced manufacturing facilities.

Since its inception, Precicon has focused on mitigating power quality disturbances that directly impact production continuity, equipment reliability, and yield. In 1998, Precicon introduced the Dynamic Sag Corrector (DYSC) technology to Singapore, initially deployed to address severe voltage sag issues in a global disk-drive media manufacturing facility. This marked one of the earliest equipment-level voltage sag mitigation deployments in the region.

Over the past 25 years, Precicon has accumulated extensive practical experience in voltage sag mitigation across semiconductor, electronics, and other critical manufacturing sectors. Its scope of services extends beyond equipment supply to include voltage sag measurement, verification, and performance validation at both equipment and facility levels. These assessments are conducted in alignment with SEMI F47 requirements and, where necessary, extended beyond the standard to address real-world grid behaviour and process sensitivity.

To date, Precicon has delivered and commissioned more than 1,500 voltage sag mitigation systems, engineered and installed by competent engineers. This experience base is supported by long-term operational data, enabling evidence-based design, specification, and validation of voltage sag solutions to ensure stable, resilient, and uninterrupted manufacturing operations.

References:

1. *EMA: https://ema.gov.sg*
2. *SPGroup: https://www.spgroup.com.sg*
3. *SEMI: https://semi.org*
4. *IEEE: https://ieee.org*
5. *Rockwell Automation: https://www.rockwellautomation.com*
6. *LKH Precicon: https://www.precicon.com.sg*

Let's Talk!

63 Hillview Ave, #10-21,
Lam Soon Industrial Building,
Singapore 669569

sales@precicon.com.sg
www.precicon.com.sg
(65) 6672 9229

LKH PRECICON