Utility Reliability Metrics for *New E-conomy* Processes

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Introduction

The US industrial economy has been powered by the electric grid for the past 100 years. The quality of electrical power has been key to economic growth and improving industrial productivity levels. In the industrial economy, power reliability (PR) was the important metric and was measured by the frequency of power interruptions, typically 2-3 per year. In the new digital economy, this definition is very limited and does not adequately address equipment and process sensitivity. Microprocessors, communications, and industrial process control equipment, the building blocks of the new digital and Internet *E-conomy*, are often disrupted by very short duration voltage dips and sags which occur 20-30 times per year. This leads to more frequent and costly process and economic disruptions, even as the 'lights stay on'. These short duration power quality (PQ) 'events' cost the US economy over $150 billion every year due to lost productivity [1].

The term 'power quality' has recently achieved a high level of visibility due to the needs of the digital economy. The distinction between power reliability and power quality is often blurred. Power reliability solutions, such as back-up generators and microturbines, often claim to be power quality devices, and vice-versa. A popular measure of utility reliability, as proposed by Mark Mills and Peter Huber of The Gilder Group, uses the percentage of time that the utility voltage is within nominal spec as a direct measure of reliability [2]. For instance, a utility voltage out of spec for 2000 seconds per year implies a 'utility reliability level' (URL) of 99.99% (or 4 nines). This reliability metric also fails to distinguish between power reliability and power quality; it also fails to distinguish the impact that each has on processes in the *New E-conomy*.

This paper suggests a segmentation of the power quality and power reliability markets based on a simple metric, the Downtime Amplification Factor (DAF), which provides valuable insight into the selection of appropriate solutions. An alternate measure of 'effective' and perceived utility reliability, the 'Process Utility Reliability Level' (PURL) is also proposed and more accurately reflects the impact that power quality events and solutions have on sensitive equipment and processes. Effective solutions, meeting the needs of power reliability and power quality, are also discussed. Solutions such as SoftSwitching's *Dynamic Sag Corrector*™ are shown to provide unique value for protecting sensitive processes.

Utility Reliability Metrics

Utilities attempt to deliver a voltage, typically within +/-10% of a 'nominal' value, to its customers at all times. A power reliability event occurs when a power outage occurs, typically lasting for 2 seconds to several hours. A power quality 'event' occurs whenever the voltage deviates from this 'nominal' band, typically for a very short time. Computers, digital controllers, and sophisticated industrial processes are at the heart of the *New E-conomy* and can shutdown when the voltage fluctuates from the nominal band for as little as 0.02 seconds (such short duration 'events' are often referred to as voltage sags). The old industrial economy used less sophisticated electromechanical devices that were sensitive to long outages, but not sensitive to voltage sags. *New E-conomy* equipment and processes tend to be very sensitive to voltage sags.

Process sensitivity to voltage sags abound in virtually every industry sector. Examples include:

- A plastic extruder in Mississippi experiences a shut down of its 14 extrusion lines between 10-15 times a year. Each shutdown entails a 4-6 hour restart process and generates a mountain of scrap. Monitoring the incom ing power with the help of the local utility revealed that voltage sags of less than ¼ second duration, primarily a result of nearby thunderstorms, caused virtually all the plant shutdowns.
- A major US auto manufacturer loses anywhere from 10-30 cars when production is interrupted by a voltage sag at an assembly plant. Such 'events' occur 10-20 times per year at <u>each</u> plant for all auto manufacturers.

- Fiber-optic cable bundles, at the heart of the telecom revolution, can snap when a voltage sag is encountered during the manufacturing process, costing cable manufacturers millions of dollars every year.
- Semiconductor fabrication houses lose millions of dollars a year in chips due to voltage sags. As a result, the semiconductor industry is the first industry group to formulate and to enforce a voltage sag susceptibility stan dard, SEMI F-47, which will specifically protect equipment and processes from voltage sags [3]. This trend is sure to be followed by other industry groups.

Most power quality 'events' are caused by factors outside a utility's control and thus can never be totally eliminated. Causes include lightning storms, squirrels in transformers, damage to utility poles, and faults in industrial plants or on the utility grid. The occurrence of such an 'event' causes a line fault resulting in the tripping of utility-protective switchgear on the specific utility line where the 'fault' occurs. However, until the fault clears (typically less than 0.15 seconds), very high currents flow in the utility system causing a short duration voltage dip or voltage sag as far as 50 to 100 miles from the location of the fault. As there could be hundreds of electric lines in that 50 to 100 mile radius, and only one faulted line which possibly suffers an actual outage, the number of voltage sag 'events' at any location vastly outnumber longer duration outage type of 'events'. Several studies, including the EPRI Distribution Power Quality Study, have confirmed that a typical utility customer in a radial distribution system may experience 2-3 outages per year, but may experience as many as 25-30 short duration voltage sags and momentary loss of power 'events' per year [4].

It is well known that many 'high-tech' industrial customers, such as semiconductor chip and automobile manufacturers, require higher levels of 'reliability' than available from typical utility grids. The high voltage transmission grid (>138 kV), independent dual distribution feeds, or highly meshed distribution grids (such as in New York city), are three distinct approaches that utilities use to improve power reliability and provide **'premium'** grade utility power. For instance, the transmission grid in most utilities or the grid in New York has not suffered an outage in over 30 years, showing extremely high reliability levels (greater than 8 nines). By way of contrast, frequent short duration voltage sags can occur, even on the 'premium' grade power grids. If a ¼ second voltage sag shuts down a sensitive process for ½ hour, the effective power reliability for the industrial customer is similar to a power loss for ½ hour. The 'down-time' for the process is amplified from ¼ second to 1800 seconds, a downtime amplification factor (DAF) of 7,200. By way of contrast, a load such as an incandescent lamp, would suffer a downtime equal to the time that the utility was out of spec, essentially a DAF of 1.

Table 1 shows how utility reliability is likely to be perceived by typical industrial customers. An example of typical power quality and power reliability events for both a 'normal' and a 'premium' utility feed for a representative utility customer are shown. It can be seen that for the event scenario shown, the normal utility customer experiences 2107.5 seconds of 'event' time per year, compared with 5.5 seconds per year for the premium utility customer. For a load with DAF=1; this would give a URL of 4 nines for the normal utility feed and 6 nines for the premium utility feed. For most old economy customers with low DAF processes, a premium power feed would thus provide adequate reliability levels.

Table 1: Perceived utility reliability based on typical utility and process characteristics

	# of events Normal utility	Time utility out of spec	Time Process is down (sec)*	DAF	# of events Premium Utility	Time utility out of spec	Time Process is down (sec)*	DAF
<1/4 sec duration	22	5.5 sec	39,600 s	7,200	22	5.5 sec	39,600 s	7,200
¼ sec to 2 sec	1	2 sec	1,800 s	900	0	0 s	0 s	-
2 sec to 5 minutes	1	300 s	1,800 s	6	0	0 s	0 s	-
>5 min (1/2 hour typ)	1	1800 s	1800 s	1	0	0 s	0 s	-
Total for all events	25	2107.5 s	45,000 s	21.35	22	5.5 s	39,600 s	7,200
Process Utility Reliability Level (PURL)	-	4 nines	2 nines	-	-	6 nines	2 nines	-

assumes that process is down for 1/2 hour per event

The impact on *New E-conomy* customers is captured in terms of effective process downtime. If a process has a high DAF and suffers, say ½ hour of downtime for every power quality or power reliability 'event', it would suffer an annual downtime of 45,000 seconds for the normal utility case (2 nines) and 39,600 for the premium utility case (2 nines). The 'Process Utility Reliability Level (PURL)' of '2 nines', for both the above cases, is thus much worse than the URL value would indicate, particularly for high DAF loads.

It should be noted that for sensitive equipment and processes (i.e., high DAF processes), the higher power reliability afforded by premium power has had virtually no impact on reducing process downtime! In fact, the downtime amplification factor (DAF) has gone from 21.3 for the 'normal' utility case, to 7200 for the 'premium' utility case. It is also clear from **Table 1** that the use of a 'back-up' solution, such as a generator, fuel cell, or microturbine, can substantially reduce the downtime of 2107.5 seconds per year, thus improving reliability. However, the slow response speed of these solutions make them ineffective against the ¼ second voltage sags, even with a 'premium' utility feed. Power quality solutions are required to dramatically improve the 'process utility reliability level' (PURL).

Existing Power Quality Solutions

Existing solutions tend to fall into two primary categories: power reliability (PR) and power quality (PQ). **Figure 1** segments the familiar magnitude-duration (mag-dur) plot into three regions: PQ, PR, and Bridge. **Figure 1** also shows an 'event' profile monitored at an industrial facility with a normal utility feed over 2½ years during the EPRI DPQ Study. **Table 1** and this data show similar trends and confirm that the PQ region covers 92% of the events by count (23/25), while the PR region covers 85% of the time that the utility is out of spec (1800/2107.5). The Bridge region covers only a small portion of the events by time or by count. However, it bridges the gap between PQ and PR solutions, making possible integrated solutions that protect against 100% of the 'events' shown in **Figure 1.**

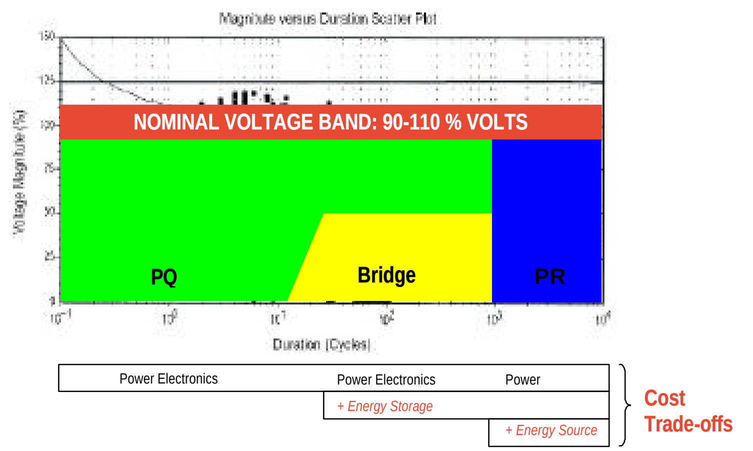
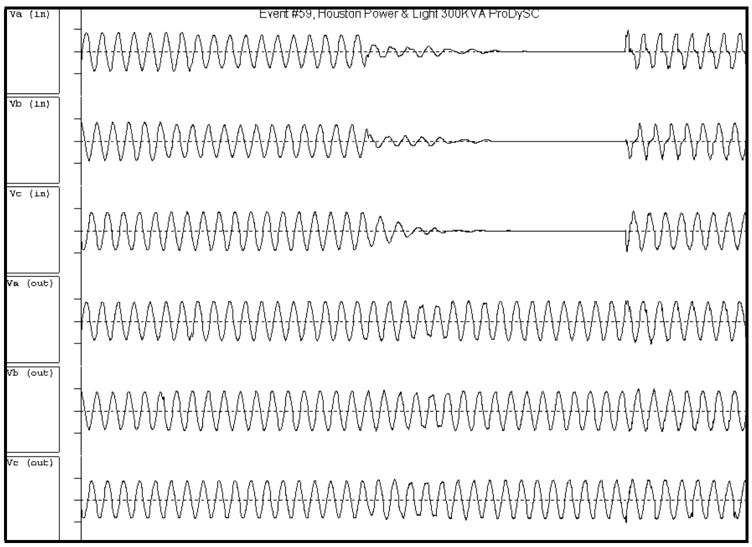


Figure 1

All three regions (PQ, Bridge, and PR) place unique demands on solutions needed to cover the respective spaces. The PR region, due to its needfor sustained operation without the utility, requires a continuous energy source. PR solutions include back-up generators, microturbines, and fuel cells. This is also the region that most distributed resource (DR) needs map over to. The Bridge region, with its need to operate for a short period of time (typically 1/4 second to 60 seconds), requires significant energy storage in the form of batteries, flywheels, ultracompacitors, or superconducting coils.. In addition, power electronics is required to condition and convert the stored energy to a utility compatible voltage. For the PQ region, the required fast response necessitates the use of power electronics. SoftSwitching's *Dynamic Sag Corrector*™, (*DySC*™ - pronounced 'disk') for instance, protects against deep voltage sags, as well as momentary loss of power, using only power electronics and minimal energy storage [5]. Other solutions, such as uninterruptible power supplies (UPS), use power electronics and one of the energy storage media from the 'Bridge' region. If we assume that the three technology components (i.e., energy source, energy storage, and power electronics) have similar cost on a mature product basis, we can deduce the cost effectiveness of the various types of solutions, as summarized in **Figure 1**.

For a 'premium' utility feed, it is clear that all 'events' fall into the PQ region. Virtually 100% of all 'events' would be covered by a lower cost PQ solution such as SoftSwitching's Dynamic Sag Corrector™, giving an effective PURL of 8 or 9 nines. This reliability level would not be significantly improved even with fully integrated solutions. This implies that for industrial processes with 'premium' utility feeds, a simple and cost effective solution such as the DySC™ can deliver the highest level in power quality demanded by high DAF applications such as server farms, semiconductor manufacturing, automotive manufacturing, and fiber optic cable manufacturing. Even with 'normal' utility feeds, the DySC™ can improve process utility reliability levels (PURL) by almost an order of magnitude, a substantial improvement.

The DySC™ represents a new power quality solution category that specifically targets high DAF processes, the heart of the New E-conomy. Customers include major automotive manufacturers, semiconductor equipment manufacturers, fiber-optic cable manufacturers, plastic extruders, steel mills, as well as food and beverage processing. The DySC™ also allows semiconductor manufacturing equipment to conform to the SEMI F-47 standard. Figure 2 shows recorded input and output waveforms for a 300 kVA DySC™ operating at an industrial computer facility in Texas. The utility waveform shows a momentary loss of power for approximately 10 cycles, including a complex ring-down voltage. As can be seen, the DySC™ was able to keep the load functioning through this event.



Date	05/20/00, 17:10:39
Location	Houston Power & Light
Product	300kVA **PRO*DySC*™**
Description	three phase ring down

Summary

Awareness of voltage sags as the dominant power quality problem is growing slowly. The DPQ study and magazines such as PQ Assurance play an important role in this education. As specific information on power quality events becomes more widely available, end-use customers who own and operate sensitive processes will be empowered to select cost-effective solutions to minimize process downtime and associated costs. The semiconductor industry, with its recently introduced F-47 standard, has clearly validated the importance of voltage sag susceptibility for an industry with high DAF factors and possibly the highest costs of downtime. As costs of the PQ solutions migrate down, this trend will be duplicated in other industry sectors.

This paper has presented new metrics for evaluating utility power quality and its impact on processes. The proposed 'downtime amplification factor' (DAF) and 'process utility reliability level' (PURL) provide a very simple and intuitive means to distinguish between various power quality solutions and their appropriateness for a given type of utility feed and process. It also provides a means to reduce some of the confusion between what constitutes a power quality or power reliability solution, and clarifies under what conditions each one is appropriate. Finally, it provides a simple but meaningful linkage between the cost of a solution and its effectiveness.

As electricity demand increases and the utility grid reaches capacity limits, there will be a need for substantial additional generation resources - the opportunity for the distributed resources market. New technologies, such as fuel cells and microturbines, will have to compete with existing generation technologies. Key technical, cost, and commercial issues remain, but the prognosis is good. There is also a tremendous synergy between the power quality and distributed resources market. Power electronics companies, such as SoftSwitching, are well positioned to take the value they are creating for customers in the power quality arena and extend the same power electronics building blocks to distributed generation markets.

References:

1. Sandia report showing $150 billion loss
2. Gilder group report
3. SEMI F-47 standard
4. EPRI DPQ Study
5. SST PQA Paper