Delivering Client Solutions & Satisfaction

White Paper

Case Study Revisited

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Our company specializes in identifying and correcting electrical system deficiencies as a means to improving equipment performance, efficiency, and reliability. This paper revisits a Case Study [that we prepared for a 2003 power problem mitigation project] for the purpose of creating awareness that power quality improvement requirements continue to increase – for all types of facilities.

Conditions [Copied from 2003 Case Study Report]

Community Hospital laboratory technicians identified problematic conditions that compromised their ability to provide essential services; which also presented life-safety concerns in that particular environment:

- Intermittent Equipment Disruption – Process Restart or "Do Over" Required
- Random Equipment Lockup – System(s) Reboot and Recalibration Required
- Equipment Lockup Every Time Electrical Supply Transferred Between Utility and Standby Generator – System(s) Reboot and Recalibration Required
- Intermittent Image Problems with Monitors, Including Changing Colors and Distortion – System(s) Reboot and Recalibration Required
- Intermittent Data Errors, Data Contamination, or Data Loss – Process "Do Over" Required
- Random Equipment Component Failure – Downtime Caused Process Backlog
- Premature Equipment Failure – Downtime Caused Backlog and Placed Mission At Risk

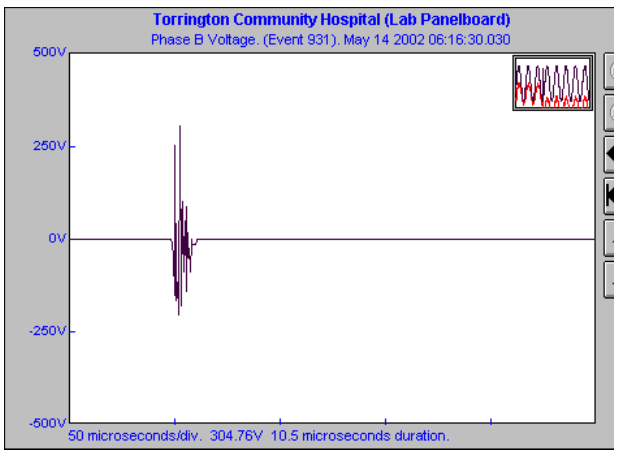
Solution Results [Copied from 2003 Case Study Report]

The following graphs show a "before and after" comparison of power events recorded at the hospital Laboratory branch circuit panelboard during 24-hour periods. It is readily apparent that implementation of our recommended solutions yielded the intended results. However, the "real success indicator" [at least for plant operations staff] was achieved when the Laboratory staff quit incessantly complaining about recurring equipment problems!

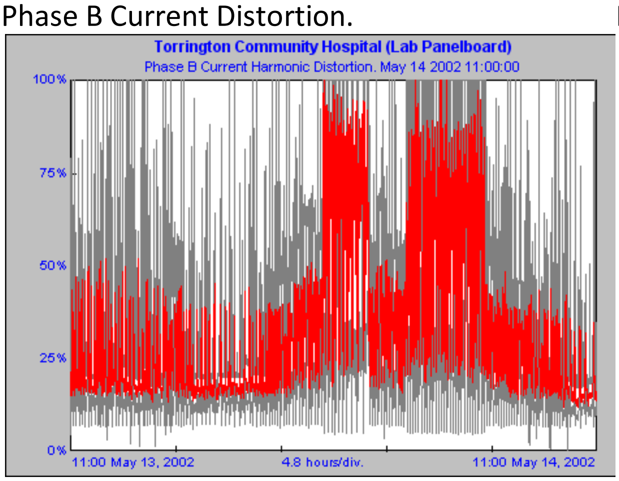
BEFORE Data was collected
05/13/02 11:00:00 - 05/14/02 11:00:00

Impulses:

Impulses are shown on the left side of the Power Tolerance Envelope. They are relatively high frequency voltage excursions of short duration. When of significant magnitude and duration, these disturbances can cause malfunction of sensitive electronic equipment and damage both components and insulation. **During the monitoring period 151 impulses occurred on the power conductors at the monitoring location.** Event 931, the largest impulse is shown below.



Phase B Current Distortion.



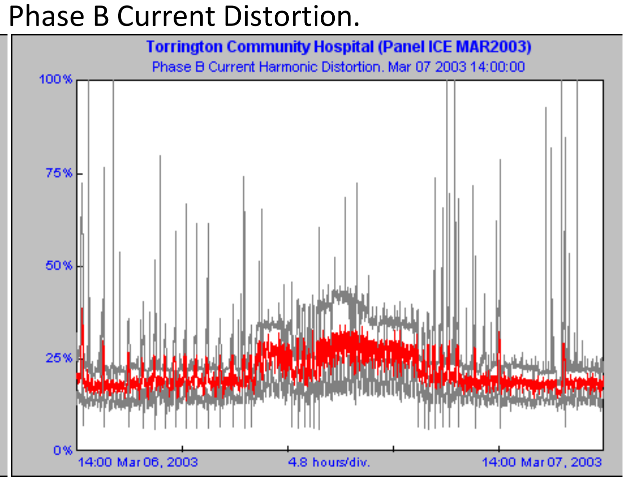
Min.	12.05%	May 14 2002 10:07:00
Avg.	**33.40%**	
Max.	113.0%	May 14 2002 03:52:30

AFTER Data was collected
03/06/03 14:00:00 - 03/07/03 14:00:00

Impulses:

Impulses are shown on the left side of the Power Tolerance Envelope. They are relatively high frequency voltage excursions of short duration. When of significant magnitude and duration, these disturbances can cause malfunction of sensitive electronic equipment and damage both components and insulation. **No impulses occurred during the monitoring period.**

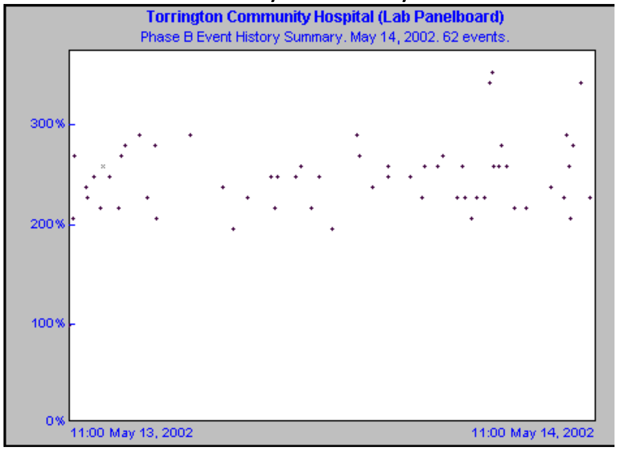
Phase B Current Distortion.



Min.	13.75%	Mar 06 2003 19:01:00
Avg.	**21.92%**	
Max.	38.92%	Mar 06 2003 14:15:30

BEFORE Data was collected from
05/13/02 11:00:00 - 05/14/02 11:00:00

Phase B Event History Summary.



Phase B Event Tolerance Summary.

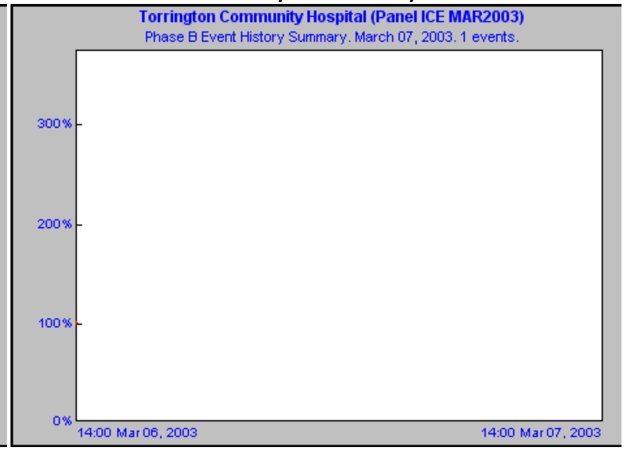
Torrington Community Hospital (Lab Panelboard) (CBEMA)
Phase B Event Tolerance Summary. May 14, 2002. 62 events.

	Type I	Type II	Type III
Start Duration	1 us	8.333 ms	2 sec
End Duration	8.333 ms	2 sec	1 day
Total Events	61	0	0
Total Faults	0	0	0

	Event No.	Amplitude	Duration
Longest Type I Event	1131	190.4V	48.5 us
Largest Type I Event	931	304.7V	10.5 us
Longest Type II Event	N/A		
Largest Type II Event	N/A		
Longest Type III Event	N/A		
Largest Type III Event	N/A		

AFTER Data was collected from
03/06/03 14:00:00 - 03/07/03 14:00:00

Phase B Event History Summary



Phase B Event Tolerance Summary.

Torrington Community Hospital (Panel ICE MAR2003) (CBEMA)
Phase B Event Tolerance Summary. March 07, 2003. 1 events.

	Type I	Type II	Type III
Start Duration	1 us	8.333 ms	2 sec
End Duration	8.333 ms	2 sec	1 day
Total Events	0	0	1
Total Faults	0	0	0

	Event No.	Amplitude	Duration
Longest Type I Event	N/A		
Largest Type I Event	N/A		
Longest Type II Event	N/A		
Largest Type II Event	N/A		
Longest Type III Event	1	120.4V	23.999 hr
Largest Type III Event	1	120.4V	23.999 hr

Corrective actions that produced these impressive results included: (1) upgrading branch circuit wiring, (2) replacing several line-interactive uninterruptible power supply units with true-online, double-conversion UPS units, and (3) installing a surge protective device equipped with enhanced transient filtering on the hospital branch circuit panelboard supplying Laboratory equipment.

Benefits [Results of 2003 Case Study Report]

The "before and after" graphs were sufficient for hospital administrators to recognize the significant improvements resulting from the corrective actions. This multi-state healthcare corporation then awarded our company annually renewable professional services contracts that provided them consulting services for multiple electrical system upgrades to this hospital, in addition to providing them with "on call" support whenever needed.

While clients soon recognize operational improvements following implementation of our various recommended power quality improvement solutions, they are seldom interested in funding follow-up activities required to complete a Case Study. End-user feedback such as "equipment no longer [fails, shuts down, locks-up, requires unscheduled reboot]" is accepted as "good enough" by many organizations; however, this client recognized the benefits afforded by a metrics-based comparison of post-construction conditions to pre-construction conditions. These "before and after" comparisons may be used to:

- calculate Return-on-Investment (ROI),
- determine whether the desired result was achieved,
- evaluate the need for further problem mitigation activities,
- evaluate the benefit/cost for additional enhancements, and
- justify project expansion [as in this original Case Study].

Power Quality [Then & Now]

The application of power quality Codes & Standards has continued to evolve since my entry into the field in 1986. The proliferation of sensitive electronic equipment, combined with the deteriorating power grid, presents ever-increasing challenges to reliable operations for all facility types.

The problematic power conditions identified in our 2003 Case Study have worsened in the intervening years. They are not limited to hospital laboratories, but are common throughout healthcare facilities, other types of laboratories, data centers, communications facilities, corporate office buildings, military facilities, manufacturing plants, processing plants, colleges & schools, casinos, oil & gas wells, truck stops, convenience stores, etc. – i.e., wherever electronic equipment is installed.

In 2013, the power grid received a "D+" grade on its report card from the American Society of Civil Engineers. The power grid grade card rating means the energy infrastructure is in "poor to fair condition and mostly below standard, with many elements approaching the end of their service life." It further means a "large portion of the system exhibits significant deterioration" with a "strong risk of failure."

Weather-related power outages doubled 2003-2012. Non-weather related outages also increased during that time.

Surge Protection [Today]

While there is no single "silver bullet" for correcting power problems or improving equipment performance, efficiency, and reliability -- each site and set of conditions is unique -- the system-wide installation of high-end Surge Protective Devices (SPDs) should be considered a standard electrical system component. Electronic loads, including lighting and system controls, are particularly vulnerable to voltage transients. SPDs equipped with enhanced transient filtering provide the most immediately apparent and most cost-effective means of improving power quality.

Changes in 2014 National Electrical Code included new Article 700.8: "A listed SPD shall be installed in or on all emergency systems switchboards and panelboards." NEC Article 708.20 (D): "Surge protection devices shall be provided at all facility distribution voltage levels."

NFPA 780-2017 Standard for the Installation of Lightning Protection Systems, Section 4.20, covers surge protection. When a LPS is installed, SPDs are required at the service entrance for the electrical distribution system and all communication systems. 80% of equipment failure and misoperation is caused by transient voltage activity generated by equipment located within the facility. It is recommended that SPDs be deployed in a comprehensive system approach; SPD at the service entrance location, SPDs at distribution and branch locations, and SPDs installed at point-of-use equipment. SPDs should be sized in accordance with their location within the lightning protection zone.

IEEE has recommended cascaded deployment of SPDs for the past twenty years. My company's primary focus in deploying TVSS/SPDs has been power quality enhancement; however, numerous studies have shown the typical payback period for SPD expenditures to average two years. This short payback period makes system-wide SPD deployment a wise business decision – in addition to being a prudent engineering solution.

We have 30-years experience in the application of Transient Voltage Surge Suppressors (TVSS) and Surge Protective Devices (SPDs). The naming preference for these devices has flip-flopped over the years, with SPD now [seemingly] standardized among [most] Codes, Standards, and manufacturers. There have been hundreds of TVSS/SPD manufacturers, many of whom have long since come and gone. Our company has always limited the number of TVSS/SPD manufacturers that we use, supply, or specify – electing to use trusted make/model devices that best meet our client's requirements.

Our company first supplied *Total Protection Solutions* Surge Protective Devices (SPDs) in January 2004. Since 2006, our facility survey report recommendations have frequently included model specific *Total Protection Solutions* "ST" or "LP" Series SPDs for every switchboard, distribution panelboard, branch circuit panelboard, and critical point-of-use equipment. These *Total Protection Solutions* devices typically provide the best "bang for the buck" in the industry, particularly when factoring in their 30-year "Free Replacement" warranty. The 1-3 year payback period combined with long-term improved equipment performance and reliability supports organizational goals for sustainable operations.

For clients with large facilities or multiple locations, we frequently advocate a 3-Step approach for improving equipment performance, efficiency, and reliability:

- Step 1: Deploy enhanced transient filter equipped SPDs using a cascade system approach throughout the facility. Benefits are quickly realized, as the required survey and installation is straightforward. This investment is inexpensive relative to expected capital improvement. In addition, the removal of transients makes it easier to identify remaining power and grounding system deficiencies (Step 2).
- Step 2: Follow-up with comprehensive power quality survey & analysis to identify remaining problematic conditions and opportunities to further improve equipment performance, efficiency, and reliability. Common findings are listed below.
- Step 3: Implement all recommendations developed during Step 2 survey & analysis in a timely manner. Unfortunately, too many organizations procrastinate in taking action, only to suffer costly and sometimes catastrophic consequences. Funding power quality upgrades falls under the "pay now or pay [more] later" category.

Common Survey & Analysis Findings

Improperly installed SPDs. Correct installation is critical for the proper operation of SPDs. Installation is simple, yet [all too often] electricians fail to comply with the manufacturer's instructions or NEC Article 285. A *Code* section frequently violated is NEC 285.12, which states "The conductors used to connect the SPD to the line or bus and to ground shall not be any longer than necessary and shall avoid unnecessary bends."

Undersized utility transformers and service conductors. Insufficient service capacity is an all too-common occurrence for smaller facilities. This condition is frequently caused by incremental cooling equipment upgrades required to keep pace with electronic equipment "load creep" over time. This is particularly true for buildings with 120/240V single-phase, 120/240V high-leg delta three-phase, or 208/120V wye three-phase service commonly found in small markets. Existing 480Y/277V service and building electrical distribution equipment is not immune from overloading; e.g., network topology changes may add hub functionality to communications service provider facilities, thereby increasing equipment power and cooling demands. A common misconception is that electrical utilities insure that power capacity supplied a facility is 'automatically' increased as consumption increases – it is incumbent upon the customer to request service upgrades.

Utility service voltage not in compliance with tariff. ANSI C84.1 establishes, for each nominal system voltage, two ranges for service voltage and utilization voltage variations, designated as "Range A" and "Range B". ANSI C84.1 stipulates that the occurrence of service voltages outside of "Range A" [nominal ±5%] limits should be infrequent. When they occur, on a sustained basis, corrective measures shall be undertaken within a reasonable time to improve voltages to meet "Range A" requirements. Electric utilities do not monitor facility service voltage. It is incumbent upon the customer to meter service voltage and request transformer tap or voltage regulator adjustments.

Excessive voltage unbalance (imbalance). Unlike voltage range (nominal ±5%, ±10%), voltage unbalance is rarely metered and remains inadequately addressed in tariffs. Unbalanced voltages are unequal voltage values on 3-phase circuits that can exist anywhere in a power distribution system. Single-phasing is the ultimate voltage unbalance condition for a 3-phase circuit; however, non-phase-loss voltage unbalance is an increasing occurrence as the [undetected] cause of equipment failure. Selection of appropriate solution requires power quality metering to determine whether the voltage unbalance source is the utility service, unbalanced loads within the facility, or both.

Excessive voltage drop resulting from undersized conductors is a chronic condition in most facilities that we survey. Failure to adequately adjust (derate) conductors for ambient temperature, number of conductors in a conduit, and long circuit lengths is widespread. Low voltage at point-of-use causes improper, erratic, or no operation - and damage to the equipment. Low voltage at point-of-use results in poor efficiency and wasted energy. Heating at a high resistance connection may result in a fire at high ampere loads.

Premature failure and inefficient operation of outdoor HVACR equipment. NEC Table 310.15(B)(3)(c) *Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops* became a requirement in the 2008 NEC. Though not a *Code* requirement, as is the case with rooftop locations, prudent installation practice dictates increasing conductor size for ground level outdoor units located on asphalt or beside metal buildings where subjected to sunlight exposure and heat reflection.

Harmonics. The trend of high levels of harmonic voltage distortion will continue as a result of the anticipated increase in the penetration of newer energy-efficient technologies, which tend to be harmonic-rich loads.

Harmonic currents generated by non-linear electronic loads can reduce system efficiency, cause apparatus overheating, and increase power and air conditioning costs. As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation.

Commercial and industrial consumers are responsible for complying with IEEE 519-2014, *Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*. It is important to realize that IEEE 519 specifies harmonic limits for the point of common coupling (PCC) between the facility and the public power supply system – it should not be applied to individual pieces of equipment or at locations within a user's facility. In most cases, harmonic voltages and currents at these locations are significantly greater than the limits recommended at the PCC due to lack of diversity, cancellation, and other phenomenon that tend to reduce the combined effects of multiple harmonic sources to levels below their algebraic summation.

Objectionable ground currents. Large amounts of current flow on ground can adversely affect equipment and trigger ground fault circuitry. Two common wiring errors are:

1. Improper bonding of neutral bus or neutral conductor to equipment ground.
2. Improper use of equipment ground in lieu of neutral. Example: 208V or 240V HVACR equipment was supplied phase-phase power. Lacking a neutral, HVACR tradesmen often used one phase and an equipment grounding conductor to power 120V receptacle.

Step-Down Transformer type and installation. Existing step-down transformers are predominately inefficient General-Purpose type, along with some mix of K-Factor type. General-Purpose transformers are not suited for high concentrations of the non-linear loads now present in most facilities. K-Factor is the most inefficient transformer type, particularly when lightly loaded. Step-down transformers may not be properly grounded. This *Code* violation not only poses a safety issue, but causes equipment damage, process disruption, and shortened equipment life-cycle. Payback period is about 5 years for replacement with energy efficient transformers; harmonics mitigating type as needed.

Surveys & Analysis

Power Quality Surveys: comprehensive monitoring at key locations for the minimum 7-day period stipulated in section 6.4.2.5 of the IEEE 1100 Standard, *Recommended Practice for Powering and Grounding Electronic Equipment*. We usually augment the data collected at the 7-day period locations with data collected at additional locations using shorter monitoring periods.

Combination 30-day Load Study Metering / Power Quality Analysis Surveys: often prescribed where electrical system modifications or load changes are anticipated. A 30-day load study metering period complies with the minimum duration requirement stipulated in NEC 220.87 Determining Existing Loads. Each survey is customized to meet the client's requirements and the unique characteristics of the facility. Input from key staff is not only encouraged, but is sought out.

The payback period for power quality improvements ranges from 1-3 years for most equipment and services. While we advocate improving energy efficiency, and even sell ultra energy-efficient transformers, the return-on-investment (ROI) for power quality improvements far exceeds the ROI for energy efficiency investments. Leveraging improved equipment performance, efficiency, and reliability drives savings and sustainability.

I am available to discuss this document or any aspect of facility power quality.

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