Power Quality Overview

Understanding power disturbance analysis, fault direction, signatures, EN50160, etc

Alec Rancourt, jr. eng.
Power Qualty Sales Expert

Life Is On Schneider Electric

Power Management Offer Portfolio

Measure

Gather accurate power and energy data from key distribution points, monitor power quality, log events

Interoperability
Standard Industry protocols and form factors
Customization: scalability in size and performance

Understand

Turn data into meaningful, actionable information for you and your stakeholders

Robust, flexible software platform architectures
Real-time energy consumption monitoring
Dynamic control interfaces
Real-time and historical power quality analysis

Act

Make timelier, intelligent decisions based on valid, actionable information

Increased energy efficiency and cost savings
Maximize electrical network reliability and availability
Optimize electrical asset performance

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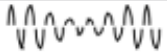
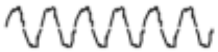
Different types of Power Quality problems: PQ Fundamentals

In most cases, your Electrical Energy provider provides you *almost* perfect Electrical Power. This is characterized by:

- Nominal Voltage on all 3 phases
- Nominal frequency (60.00Hz)
- Waveforms are perfectly sinusoidal
- Symmetry in all phases

If either of these characteristics vary, we have an Electrical Power Quality problem

Disturbance category	Waveform	Effects	Possible causes
Transients		Equipment malfunction and damage	Lightning or switching of inductive / capacitive loads
Interruption		Downtime, equipment damage, loss of data possible	Utility faults, equipment failure, breaker tripping
Sag		Downtime, system halts, data loss	Utility or facility faults, startup of large motors
Swell		Equipment damage and reduced life	Utility faults, load changes
Undervoltage		Shutdown, malfunction, equipment failure	Load changes, overload, faults
Overvoltage		Equipment damage and reduced life	Load changes, faults, over compensation
Harmonics		Equipment damage and reduced life, nuisance breaker tripping, power losses	Electronic loads (non-linear loads)
Unbalance		Malfunction, motor damage	Unequal distribution of single phase loads
Voltage fluctuations		Light flicker and equipment malfunction	Load exhibiting significant current variations
Power frequency variations		Malfunction or motor degradation	Standby generators or poor power infrastructure
Power Factor *		Increased electricity bill, overload, power losses	Inductive loads (ex. motors, transformers...)

Voltage Problems – Basics

Chronic Voltage Problems

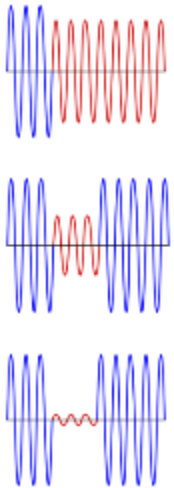
Voltage outside ±10% for > 60 seconds

Voltage Sag

Voltage < 90% for ½ cycle to 1 minute

Interruption

Voltage < 10% for >3 cycles



A Sub-Cycle problem

Effects of Harmonics

Different Perspectives

Engineering Perspective

- Nuisance tripping of circuit breaker
- Harmonic resonance
- Capacitor bank failure
- Excessive heating
- Transformer overheating
- Skin effects on cables for higher harmonic orders
- Motor winding burnt (dv/dt) & hunting
- Neutral overloading (double neutral)
- Causing EMI to sensitive signals
- Problems to generators

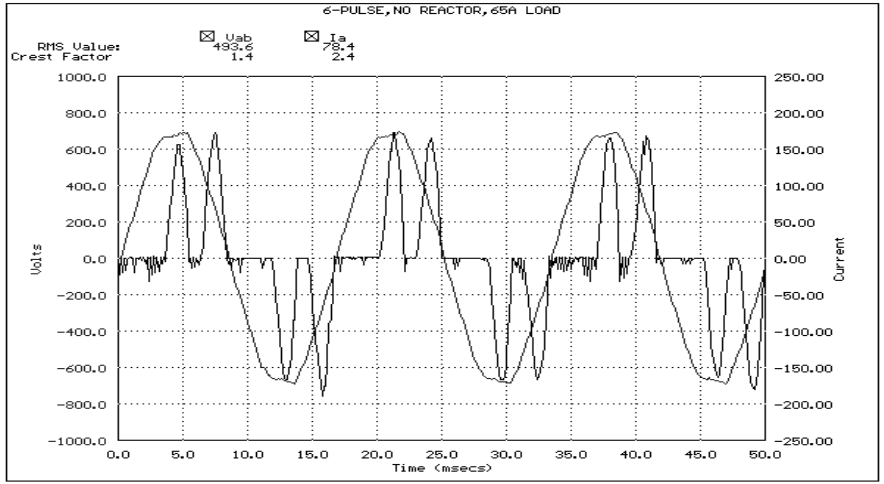
Business Perspective

- Increased maintenance and replacement cost (OPEX)
- Interruptions and downtimes cost
- Reduced system capacity and thus increase CAPEX by unnecessary of expansion.

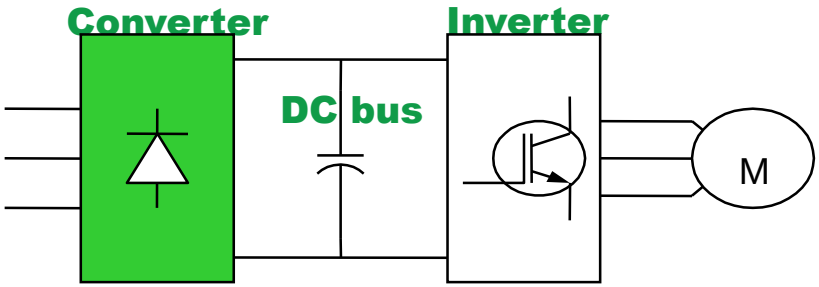
PWM VFD without 3% Line Reactance

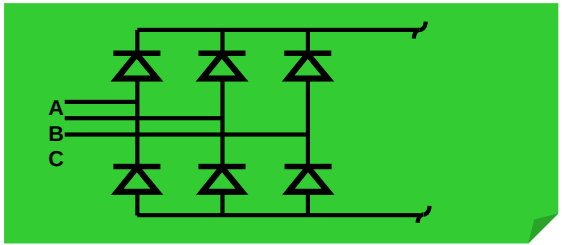
Current Distortion:

THDi ≈ 90%



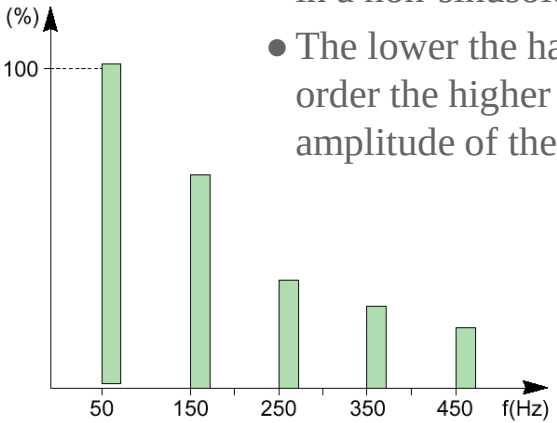
Basic PWM VSD

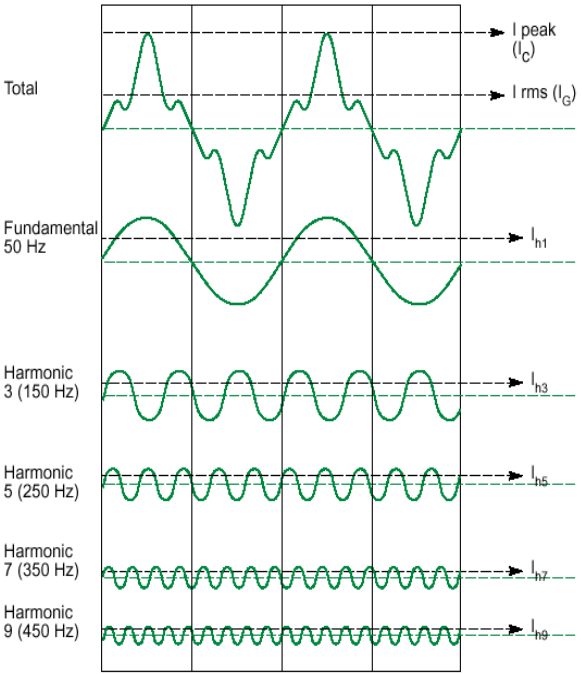




Harmonics:Fundamentals (cont.)

- Power source supplies the current the loads require for proper operation
- Harmonic current (Ih) is produced when an electrical device uses (draws) current in a non-sinusoidal manner
- The lower the harmonic order the higher the amplitude of the current





IEEE Standard 519-2014

Compliances, Updates, Solutions and Case Studies

Presented by: Dr John Cheng, CEng, CEM, CEA, CMVP

How to rate harmonics - IEEE 519

IEEE STD 519-2014

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
< 20[c]	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.
where

I_{sc} = maximum short-circuit current at PCC
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \le 1.0$ kV	5.0	8.0
1 kV $< V \le$ 69 kV	3.0	5.0
69 kV $< V \le$ 161 kV	1.5	2.5
161 kV $< V$	1.0	1.5[a]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Harmonic Mitigation Solutions

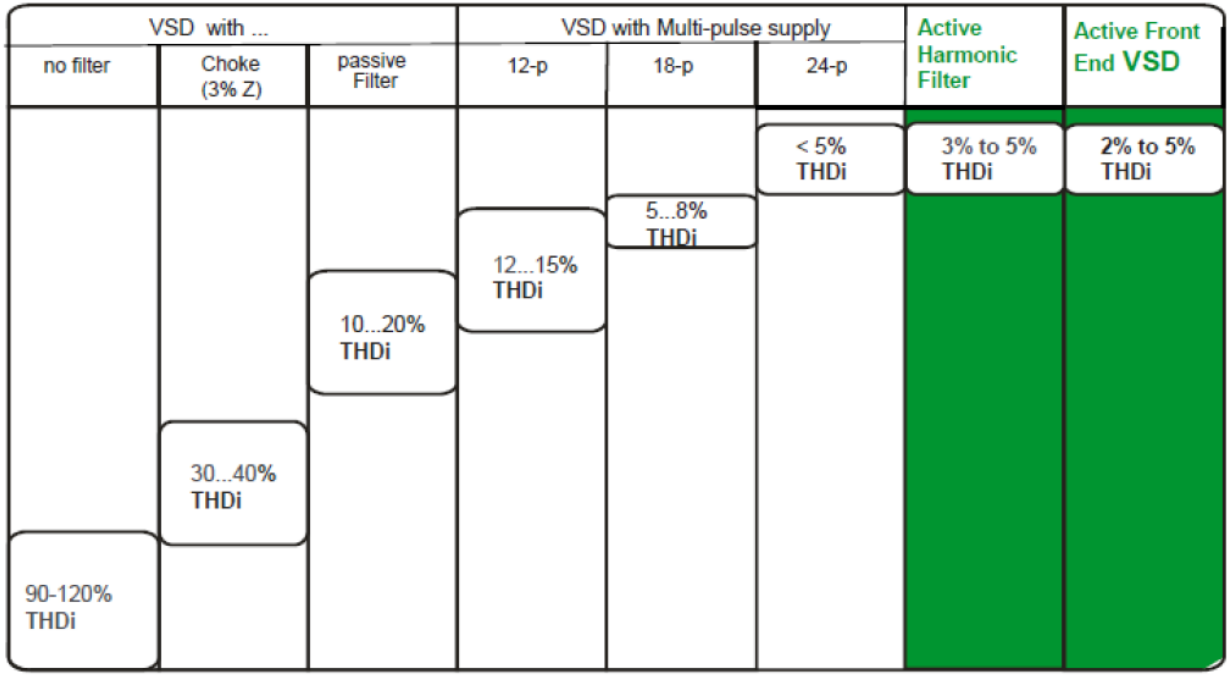
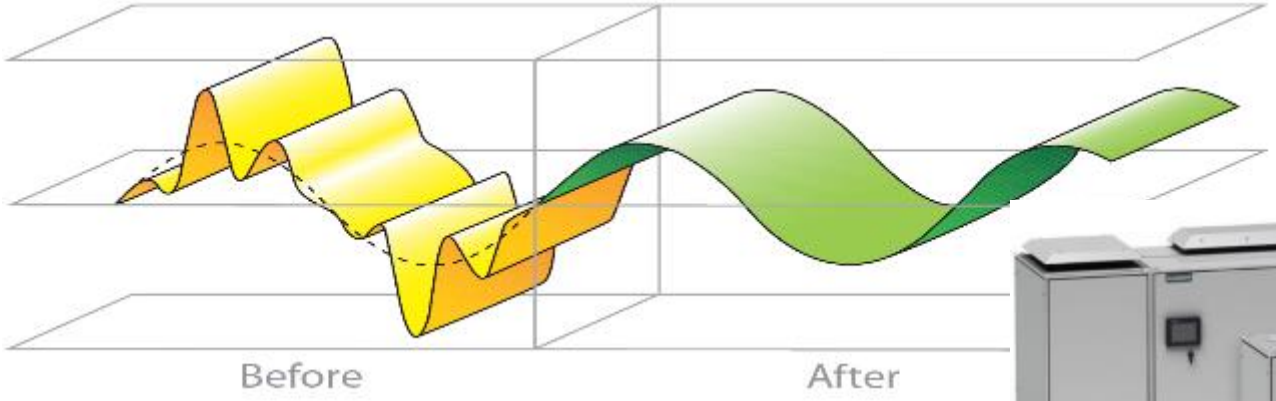


Figure 1 THDi levels achieved with various harmonic mitigation methods

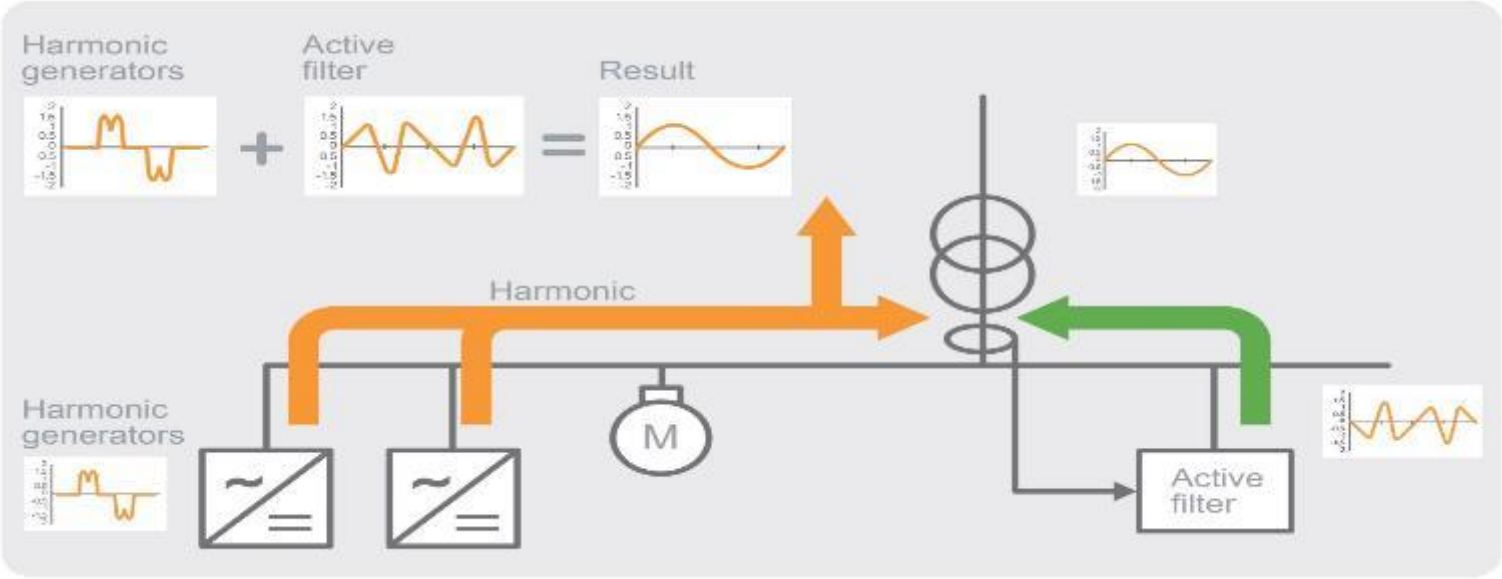
AccuSine PCS+



This selection meets or exceeds the harmonic objective of	8.00%	THDi
This selection fails to meet the objective displacement PF [Cos ϕ] of	0.9500	DPF (Cos ϕ)

AccuSine PCS+ theory of operation

AccuSine PLUS is a power electronic converter utilizing digital logic to inject corrective currents into a 3-phase power-source. These injected currents will compensate for existing harmonic currents from the 2nd to the 50th harmonic order drawn by non-linear loads connected to that grid.



AccuSine PCS+ Demo Video

AccuSine PCSn – Single Phase Harmonic Mitigation

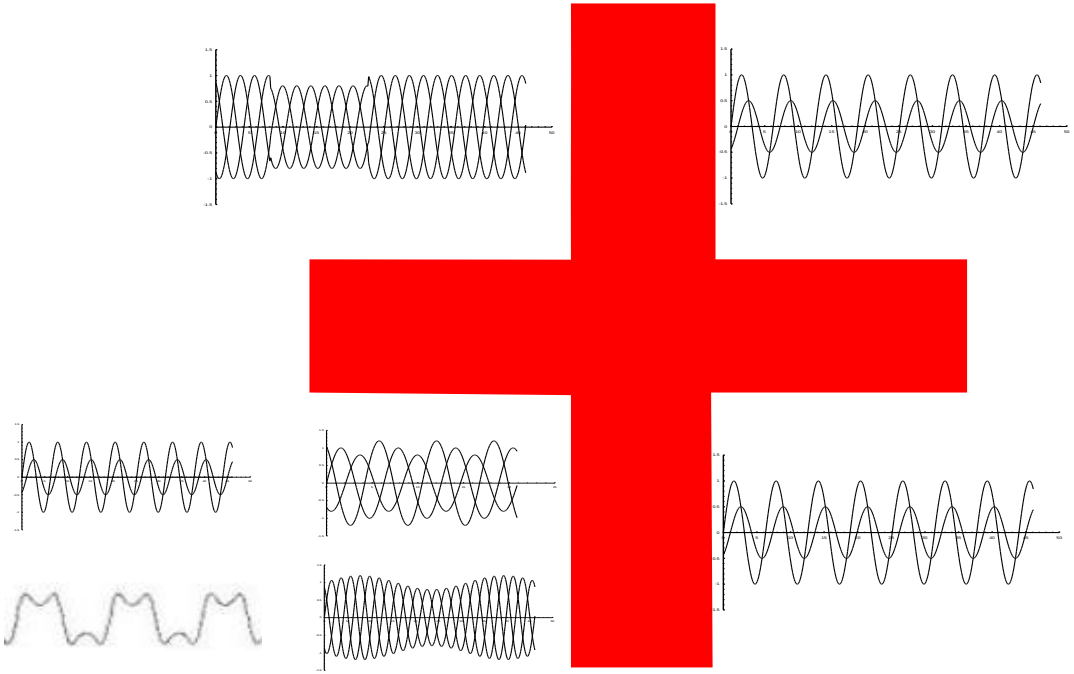
- Mitigating harmonic current for 3 phase AND neutral loads.
- Eliminating excess current in the neutral due to load imbalance.
- Correcting load imbalance and nuetral harmonic current due to single phase non-linear loads.

Building segment

Commercial & Office space | Retail space | Healthcare | Hotel & Casino | Life sciences & University

Light Industrial | Food & Beverage

Different remedies for different Power Quality problems



Power System Audits

- Investigation of specific problems with your power system
- Complete audit including measurement, analysis and reporting of power quality
- Recommendations for power quality improvement

Power Quality Audits

Case Studies

Life Is On Schneider Electric

Case study 1: Active Harmonic Filter turnkey project, hospital application

Customer Profile

In late 2013 a mid-size hospital reported the malfunction of several dialysis machines which were significantly impacting the quality of patient care. Schneider Electric's PQ Engineer performed a first PQ Audit in January. This PQ Audit led to the sale of a **PME 7.2** (Power Monitoring Expert) Power Monitoring system which was utilized, in conjunction with a fleet of PM800 Meters, sold as part of the initial construction, to measure the harmonic current produced by VSDs added throughout the facility as part of an Energy Efficiency project.

The existing situation

The hospital's air conditioning system had recently been modernized with a fleet of Variable Speed Drives (VSDs). These VSDs were polluting the hospital's electrical network and were regularly causing the new dialysis machines to malfunction. Diabetic patients were regularly sent home and asked to reschedule their treatment. The hospital's management had visibility on this problem and were eager to find someone with the knowhow to solve the issues. Schneider Electric's senior Power Quality specialists pinpointed the source of the harmonic distortion to be VSDs which were installed throughout the facility to efficiently regulate airflow and air pressure. The harmonic current produced by the VSDs was interacting with distribution transformers throughout the hospital and creating Voltage Distortion. Schneider Electric provided a turnkey proposal to design and implement PQ mitigation within the hospital's facility.

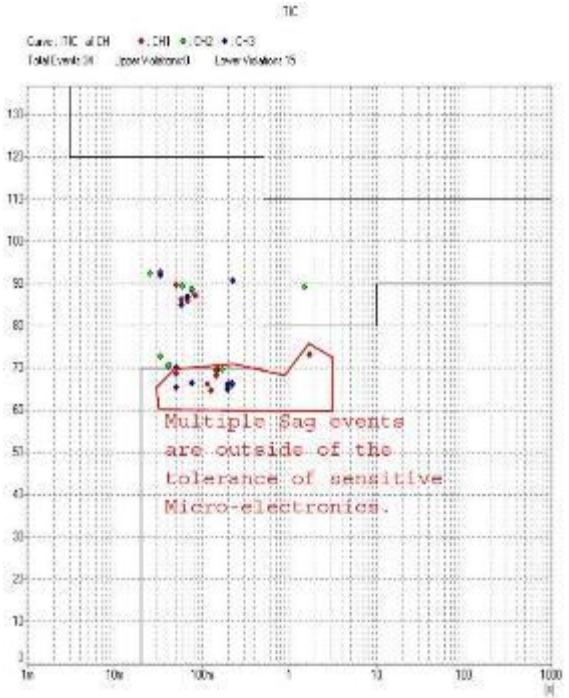
The Solution

Turnkey design & installation proposal

We sold our ability provide a turnkey proposal to comprehensively analyze and mitigate the Power Quality problems afflicting the dialysis machines. These PQ problems were severely impacting the quality of patient care and inhibiting the hospital's ability to manage diabetic patient care.

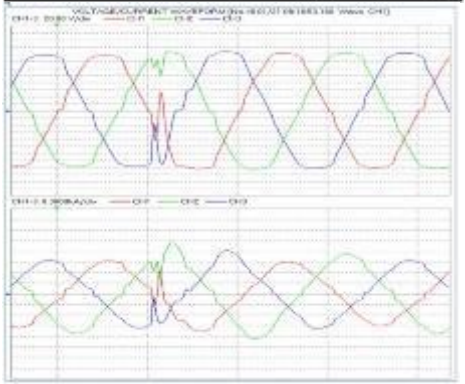
Power Quality disturbances

- 1. Voltage Distortion (aka THDv or Vthd)
- 2. Voltage Sag
- 3. Multiple Zero crossings



POWER		VOLTAGE		CURRENT	
Freq	57.813 Hz				
P1	0.0473MW	U1	116.48 V	I1	0.4268kA
P2	0.0611MW	U2	115.84 V	I2	0.5341kA
P3	0.0521MW	U3	115.70 V	I3	0.4640kA
Psum	0.1606MW	THD-U1	3.26 %	THD-I1	10.12 %
S1	0.0492MVA	THD-U2	5.79 %	THD-I2	10.71 %
S2	0.0619MVA	THD-U3	7.41 %	THD-I3	12.48 %
S3	0.0537MVA	Upk+1	157.57 V	Ipk+1	0.616kA
Ssum	0.1653MVA	Upk+2	163.26 V	Ipk+2	0.884kA
Q1	0.0152Mvar	Upk+3	165.17 V	Ipk+3	0.792kA
Q2	0.0097Mvar	Upk-1	-164.25 V	Ipk-1	-0.715kA
Q3	0.0128Mvar	Upk-2	-160.14 V	Ipk-2	-0.841kA
Qsum	0.0377Mvar	Upk-3	-159.81 V	Ipk-3	-0.736kA
PF1	0.9523	Uave	116.01 V	KF1	1.17
PF2	0.9877	Uunb	0.65 %	KF2	1.24
PF3	0.9711			KF3	1.30
PFsum	0.9716			Iave	0.4750kA
				Iunb	7.63 %

POWER		VOLTAGE		CURRENT	
Freq	59.968 Hz				
P1	0.0728MW	U1	119.09 V	I1	0.6225kA
P2	0.0872MW	U2	120.17 V	I2	0.7300kA
P3	0.0717MW	U3	120.51 V	I3	0.6059kA
Psum	0.2317MW	THD-U1	4.78 %	THD-I1	7.94 %
S1	0.0741MVA	THD-U2	4.72 %	THD-I2	8.86 %
S2	0.0878MVA	THD-U3	4.70 %	THD-I3	8.51 %
S3	0.0730MVA	Upk+1	163.45 V	Ipk+1	0.931kA
Ssum	0.2349MVA	Upk+2	163.81 V	Ipk+2	1.112kA
Q1	0.0139Mvar	Upk+3	164.07 V	Ipk+3	0.939kA
Q2	0.0103Mvar	Upk-1	-162.39 V	Ipk-1	-0.944kA
Q3	0.0137Mvar	Upk-2	-162.93 V	Ipk-2	-1.120kA
Qsum	0.0379Mvar	Upk-3	-163.74 V	Ipk-3	-0.940kA
PF1	0.9824	Uave	119.92 V	KF1	1.53
PF2	0.9930	Uunb	0.30 %	KF2	1.47
PF3	0.9822			KF3	1.59
PFsum	0.9863			Iave	0.8529kA
				Iunb	6.18 %



Schneider Electric offers a unique value proposal for Power Quality solutions

1. Investigate PQ problems anywhere in Canada
2. Diagnose and quantify problems onsite or remotely
3. Produce comprehensive engineering reports
4. Simulate network behavior as necessary
5. Design and deliver custom PQ mitigation solution
6. Validate performance
7. Support equipment through extended warranty and preventative maintenance

Pre-installation: Preliminary harmonic study

Voltage where AccuSine system is attached:	600	V
Point of Common Coupling (PCC)	MCC Transfomer - Secondary	
Harmonic Standard for current limits is	IEEE 519-2014	(optional)

Applied operational mode(s):

Harmonic Mitigation:	x	THDi Required:	
Power Factor Correction:	x	DPF (Cos ϕ) Required:	0.95
Percent of AccuSine PCS system assigned for Harmonic Mitigation:			

Equipment list for NONLINEAR LOADS

Item	Quantity	Size	Unit of Measure	Type of Equipment	Rectifier pulses	Installed Impedance (%Z)	Maximum Capacity Utilized	Full Load Displacement PF
1	3	75	HP	PWM VFD	6	3.00%	100.0%	
2	1	75	HP	PWM VFD	6	3.00%	50.0%	
3	1	15	HP	PWM VFD	6	3.00%	100.0%	
4	2	20	HP	PWM VFD	6	3.00%	100.0%	
5	1	5	HP	PWM VFD	6	3.00%	100.0%	
6	1	1.5	HP	PWM VFD	6	3.00%	100.0%	
7	1	30	HP	PWM VFD	6	3.00%	100.0%	
8								
9								
10								

AC Motors Operating Direct-on-Line

Item	Quantity	Size	Unit of Measure	Rated Full Load PF (Nameplate)	Maximum Capacity Utilized
11	1	41	HP	0.800	80.0%
12	1	45	HP	0.800	50.0%
13	1	52.48	HP	0.800	80.0%
14	1	2.5	HP	0.800	50.0%
15					

Equivalent installed impedance:	3.00	%
Selection adjustment factor according to installed impedance:	1.20	
System Short Circuit Ratio (ShCR) @ selected PCC:	39.8	:1

IEEE 519-2014 Table 2

$I_{sc}/I_{f\,FLA}$	% TDD
<20	5%
<50	8%
<100	12%
<1000	15%
>=1000	20%

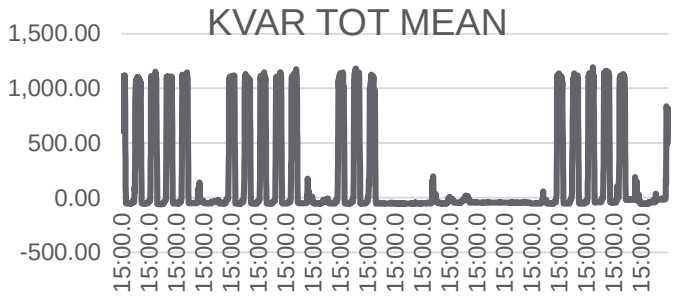
Uncorrected System				
Type of RMS Current	Original System Current Amplitudes & Total Harmoic Current Distortion		Power	
Total I_{rms}	430.1	amps	447.02	KVA
Total I_{fund}	420.3	amps	402.43	KW

AccuSine+ rating required @ system bus voltage:	81.7	amps
AccuSine+ rating required @ unit base voltage:	81.7	amps
User Selected AccuSine+ rating @ unit base voltage:	94.0	amps

Corrected System					
Type of RMS Current	Corrected Current Amplitudes & Total Harmoic Current Distortion		Corrected Power		
Total I_{rms}	420.9	amps	437.41	KVA	
Total I_{fund}	420.3	amps	402.43	KW	
Total I_{h}	22.4	amps	0.9986	Distortion PF	
Total $I_{reactive}$	141.1	amps	146.68	KVAR	
% THDi (achieved)	5.33%		0.9395	Cos ϕ	(Displacement PF)
			0.9382	Total PF	

Case Study 2: Sawmill with Power Quality Meter

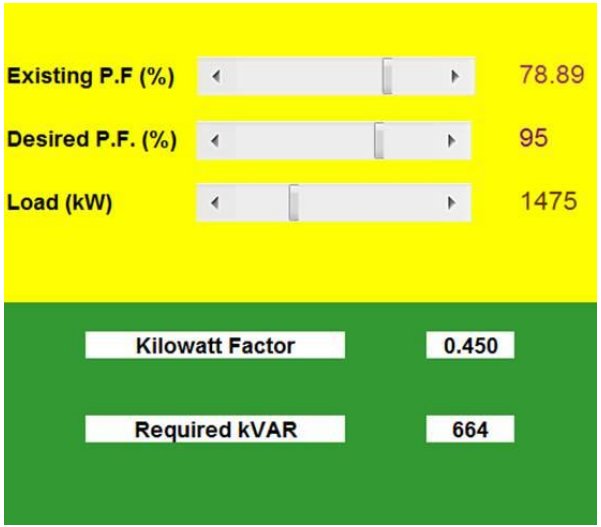
- Schneider Electric switchboard includes a PM8000 power quality meter
- Need for a power factor and harmonic study to size a capacitor bank and verify harmonics.
- PM8000 data downloaded in order to size equipment.

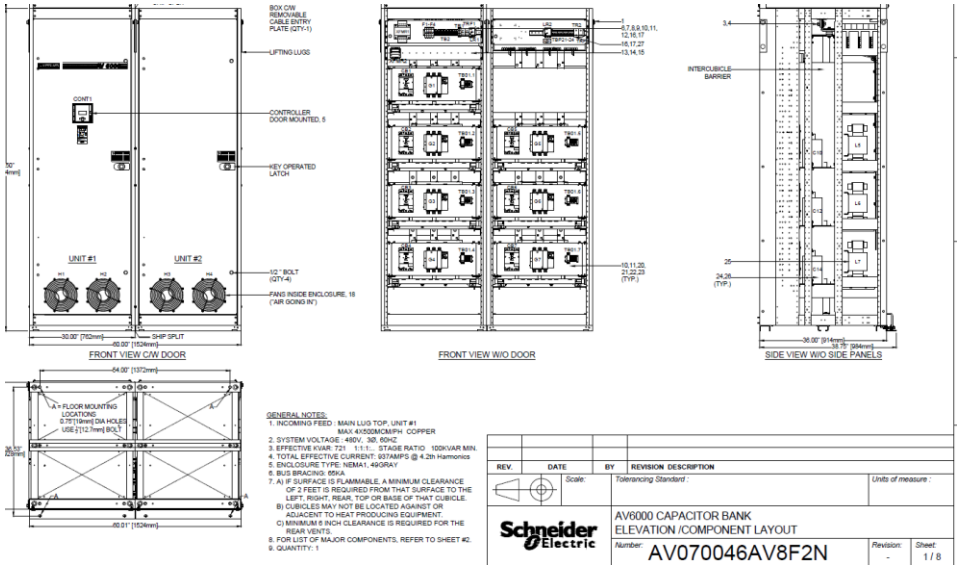


time	Vll ab mea	vll bc mea	vll ca mea	vll avg mea	v unbal me	kw to MEAN	KVAR TOT	kva tot mean	Ia mean	Ib mean	Ic mean	I avg mear	I4 mean	pf lag mean	pf lead m	freq
15:00.0	464.8563	464.7993	465.9819	465.2125	0.165626	1,289.71	1,092.16	1,691.03	2,097.47	2,089.24	2,120.10	2,102.27	0	76.226738		60.00402
00:00.0	463.7923	463.6493	464.9381	464.1266	0.174891	1,367.51	1,100.31	1,756.07	2,180.52	2,175.31	2,206.71	2,187.52	0	77.827225		60.01555
45:00.0	462.7782	462.6517	463.9631	463.131	0.17965	1,412.39	1,103.71	1,793.58	2,230.41	2,227.71	2,260.49	2,239.54	0	78.679794		59.98609
30:00.0	480.7088	479.7509	481.5206	480.6601	0.200669	935.701477	782.9775	1,221.76	1,486.59	1,461.41	1,493.38	1,480.46	0	76.928452		60.00692
15:00.0	487.0201	486.0592	487.5659	486.8817	0.169168	786.759521	609.9186	995.582642	1,183.52	1,176.25	1,192.28	1,184.02	0	79.005325		60.00294
00:00.0	472.5298	472.0681	473.4859	472.6946	0.173623	1,153.82	983.8738	1,517.30	1,866.54	1,848.04	1,871.46	1,862.02	0	76.229706		60.03032
45:00.0	465.8876	465.7168	467.1001	466.2348	0.1856	1,321.23	1,087.86	1,712.29	2,125.20	2,105.37	2,139.99	2,123.52	0	77.114098		60.00769
30:00.0	464.8081	465.0334	466.0562	465.2992	0.162713	1,364.05	1,110.07	1,759.58	2,178.21	2,177.80	2,203.34	2,186.45	0	77.476646		60.00887
15:00.0	466.1263	466.0002	467.0905	466.4057	0.14687	1,340.37	1,104.33	1,737.52	2,150.27	2,145.56	2,165.40	2,153.74	0	77.096596		59.99043
00:00.0	464.647	464.2646	465.5769	464.8295	0.162449	1,355.53	1,096.04	1,743.87	2,170.04	2,154.36	2,182.69	2,169.03	0	77.697021		60.00892
45:00.0	469.8821	469.2006	470.9959	470.0262	0.208998	1,235.02	990.695	1,584.29	1,948.01	1,945.11	1,957.62	1,950.25	0	77.95401		60.0157
30:00.0	464.884	464.5963	465.9525	465.1443	0.17396	1,348.10	1,084.35	1,731.02	2,149.12	2,138.58	2,168.66	2,152.12	0	77.828079		60.00707
15:00.0	478.8385	477.5068	479.4103	478.5852	0.230569	988.267334	756.6424	1,246.67	1,526.78	1,494.44	1,520.48	1,513.90	0	79.78212		59.99404
00:00.0	471.2125	470.587	472.0907	471.2968	0.182132	1,241.75	1,004.16	1,598.61	1,970.04	1,949.32	1,980.12	1,966.49	0	77.963272		60.01761
45:00.0	468.8351	468.2019	469.7615	468.9328	0.180448	1,250.68	1,065.74	1,644.11	2,031.83	2,006.65	2,041.37	2,027.28	0	75.999275		60.02536
30:00.0	467.9218	467.5555	468.9763	468.1512	0.176257	1,282.74	1,080.65	1,678.01	2,071.00	2,055.81	2,090.69	2,072.50	0	76.411942		59.99876
15:00.0	466.6606	466.4286	467.6901	466.9265	0.163572	1,343.34	1,098.12	1,735.87	2,143.06	2,136.56	2,168.27	2,149.30	0	77.346832		60.01216
00:00.0	464.9466	464.6219	465.9713	465.1799	0.170151	1,422.81	1,115.98	1,809.14	2,243.72	2,235.93	2,266.08	2,248.58	0	78.604263		60.02658
45:00.0	466.7253	466.4816	467.6462	466.9511	0.148951	1,397.51	1,120.51	1,792.02	2,212.14	2,208.91	2,235.30	2,218.78	0	77.94812		60.01167
30:00.0	466.9625	466.5112	467.9467	467.1402	0.173236	1,401.65	1,115.82	1,792.27	2,220.39	2,205.21	2,228.45	2,218.02	0	78.174995		59.99077
15:00.0	469.8126	469.8861	471.1617	470.2868	0.186073	1,300.97	1,080.46	1,691.91	2,074.50	2,066.44	2,099.08	2,080.01	0	76.855392		59.98222
00:00.0	479.7487	479.2746	481.4364	480.1532	0.268138	1,055.94	771.1204	1,310.85	1,586.80	1,572.43	1,602.71	1,587.32	0	81.309792		59.97657
45:00.0	492.7245	491.7632	494.3138	492.9338	0.28076	787.493835	467.4362	916.204651	1,079.63	1,066.81	1,081.94	1,076.13	0	85.959274		59.97664
30:00.0	494.4985	493.2502	496.0962	494.615	0.306739	685.192139	353.7685	775.584534	918.278	905.2935	910.9601	911.5106	0	89.225449		59.97718
15:00.0	507.5124	505.1343	508.745	507.1306	0.394656	385.855286	97.35667	410.975647	480.7441	464.8651	475.3373	473.6488	0	95.263298		59.99164
00:00.0	508.8575	506.6917	510.3699	508.6404	0.380945	366.691437	16.68254	368.08371	434.849	410.7347	421.8501	422.4779	0	99.663765		59.98527
45:00.0	510.1627	507.5304	511.7154	509.8028	0.446157	228.167633	-47.2608	234.33342	277.2282	255.3674	271.6693	268.0883	0	99.991249		59.97563

Case Study 2: Sawmill with Power Quality Meter

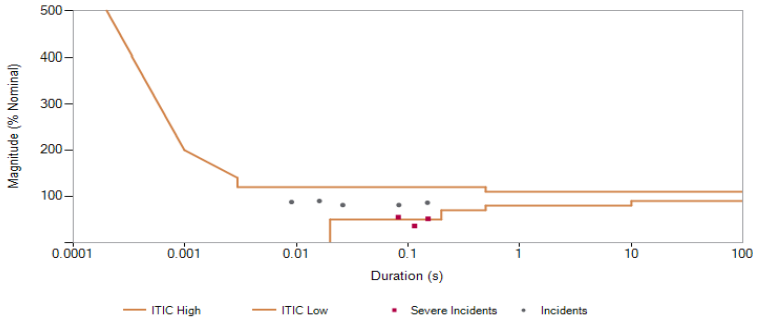
- 700kVAR sized based highest recorded peak demand
- Low THDi & THDv





Case Study 3: Industry with PME

- Industries prone to
- Voltage sags symptoms:
  - Pharmaceutical
  - Hospitals
  - Electronics manufacturer
  - Water/waste water treatment plant
  - Food & Beverage



Worst Disturbance per Incident

ID	Incident Time	Meter	Type	Phase	Duration (s)	Magnitude (%)
1	4/9/2018 2:49:48 PM	group1.Station_B001	Sag	V1	0.082	54.60
2	4/16/2018 12:50:30 AM	group1.Station_B001	Sag	V3	0.152	51.19
3	5/3/2018 5:15:01 AM	group1.Station_B001	Sag	V3	0.115	35.81
4	5/30/2018 12:01:13 PM	group1.Station_B001	Interruption	V1	5,461.043	0.00
5	6/2/2018 9:42:08 AM	group1.Station_B001	Sag	V3	0.016	89.90
6	6/4/2018 6:22:54 PM	group1.Station_B001	Sag	V2	0.026	81.07
7	6/13/2018 8:21:49 PM	group1.Station_B001	Interruption	V1	794.331	0.00
8	6/13/2018 10:56:18 PM	group1.Station_B001	Interruption	V1	624.286	0.00
9	6/24/2018 3:54:04 PM	group1.Station_B001	Sag	V1	0.009	87.68
10	7/2/2018 7:40:56 PM	group1.Station_B001	Sag	V1	0.150	86.16
11	7/4/2018 10:41:20 AM	group1.Station_B001	Sag	V3	0.083	81.16

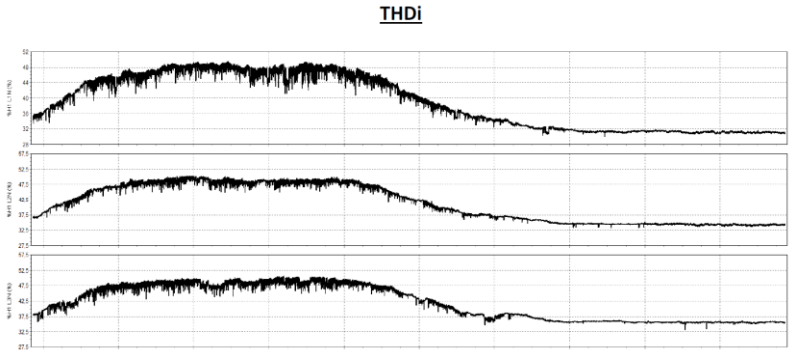
Case Study 4: Commercial Building

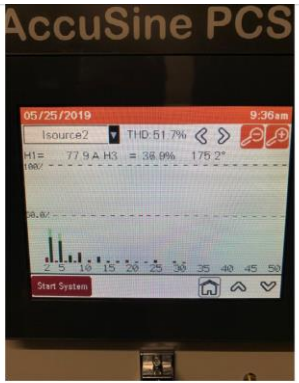
Problem

- Commercial building busbars suffered from constant noise.
- Security threat, as resulting vibrations can lead to loosening connections.
- Source from single phase non-linear loads.

Solution

- Installation of 1 PCSn active harmonic filter to reduce harmonic distorsion.
- Significantly lowered neutral current and eliminated noise.



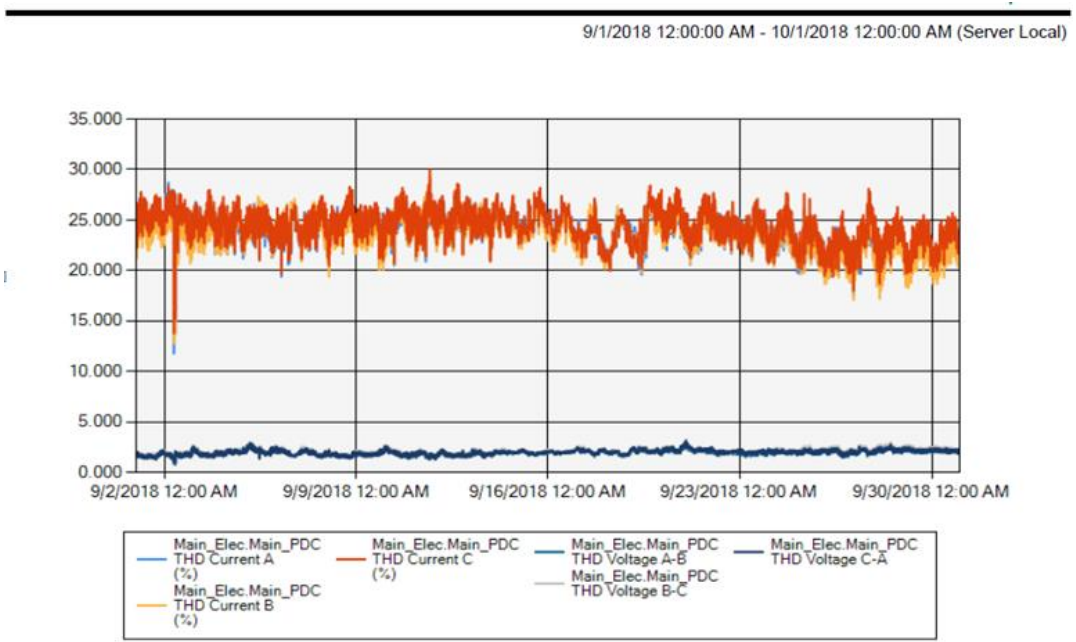


Pic. 4 Harmonic spectrum – AccuSine stopped

Pic. 5 Harmonic spectrum – AccuSine running

Case Study 5: Municipality with PME

- Water/Waster treatment plant
- High harmonics detected
- Existing capacitor bank failing.



PQ Audit Case 6: Industry with Power Advisor

Potential Issue: Excessive Voltage Harmonic Distortion Condition

Meltshop.EM03A

Device Type: 7330

Threshold: 3.00% THD

System Load Affected: 2,127,700.04 %

Comment: Excessive Voltage Harmonic Distortion Condition has been found for multiple measurements at this location. The most severe is: Voltage Total Harmonic Distortion Mean on Input V1 reached 42.04%. This indicates significant voltage waveform distortion. It would be useful to include phase voltages and currents to be logged.

Measurement	Worst As %	Average	Minimum	Maximum	At Peak Demand
THD Voltage A-B mean	**0.00 %**	**7.79%**	**0.00%**	**42.04%**	----
THD Voltage C-A mean	0.00 %	7.80%	0.00%	41.43%	----
THD Voltage B-C mean	**0.00 %**	**7.46%**	**0.00%**	**40.17%**	----

Other Cases Studies

- Lighting retrofits
- Water/waste water treatment plants
- Cannabis
- VFD retrofits
- Small/mid size industries

Life Is On | Schneider Electric

Case Study 7: Industry with ION7650

Large factory in Greater Toronto Area
suffering from process line shut downs.

- Each time there is an unplanned shut down,
- system shuts down and powder coating
- spreads across the factories,
- requiring a thorough cleaning every time.
- Exiting ION meter installed by utility
- Study determined voltage sags and interruptions

Event #	Duration (s)	Magnitude Phase1	Magnitude Phase2	Magnitude Phase3	Event Type	# phases affected	SagFighter will correct ?	Flywheel UPS will ride through ?	Timestamp
1	0.767000	0%	0%	0%	Interuption	3	No	YES	09/07/2016 8:00:08.565 AM
2	0.000065	0%	0%	135%	Interuption	2	No	YES	09/05/2016 9:48:33.482 AM
3	0.000048	127%	0%	0%	Interuption	2	No	YES	09/04/2016 12:14:18.558 PM
4	0.000065	0%	130%	0%	Interuption	2	No	YES	09/03/2016 8:40:46.923 AM
5	0.000016	0%	0%	119%	Interuption	2	No	YES	09/01/2016 6:26:46.531 AM
6	0.000016	118%	0%	0%	Interuption	2	No	YES	8/27/2016 8:08:53.866 AM
7	0.083000	48%	46%	32%	Sag	3	YES	YES	8/26/2016 5:24:38.765 PM
8	0.900000	0%	0%	0%	Interuption	3	No	YES	08/07/2016 6:44:22.174 AM
9	0.880000	0%	0%	0%	Interuption	3	No	YES	7/29/2016 6:16:42.307 AM
10	0.941000	0%	0%	0%	Interuption	3	No	YES	07/03/2016 6:55:05.439 AM
11	0.925000	0%	0%	0%	Interuption	3	No	YES	07/01/2016 6:48:08.814 AM
12	0.109000	50%	49%	56%	Sag	3	YES	YES	6/24/2016 4:27:54.614 AM
13	0.867000	0%	0%	0%	Interuption	3	No	YES	5/30/2016 12:16:31.980 AM
14	0.033000	45%	47%	31%	Sag	3	YES	YES	5/29/2016 6:58:31.446 AM
15	0.000065	133%	0%	0%	Interuption	2	No	YES	5/23/2016 11:20:57.288 AM
16	0.075000	48%	53%	52%	Sag	3	YES	YES	5/17/2016 10:01:39.796 AM
17	0.125000	55%	48%	48%	Sag	3	YES	YES	05/06/2016 7:46:17.937 AM
18	0.000016	120%	0%	0%	Interuption	2	No	YES	05/01/2016 9:53:51.004 AM

Case Study 7: Industry with ION7650

Table 1 : Summary of financial impact of the Sag Fighter™ and Flywheel UPS solutions

	SagFighter™ Solution	Flywheel UPS Solution
Number of events covered by data	5	18
Number of weeks of data	18	18
Prorated estimated number of events per year	14.4	52.0
Average event cost	$ 30,000	$ 30,000
Yearly cost of events avoided	$ 433,000	$ 1,560,000
Estimated value of investment required for implementation of complete solution for all 10 process lines	**$ 1,593,000**	**$ 2,484,000**
Simple Payback in months	44	19
Simple Payback in years	3.68	1.59

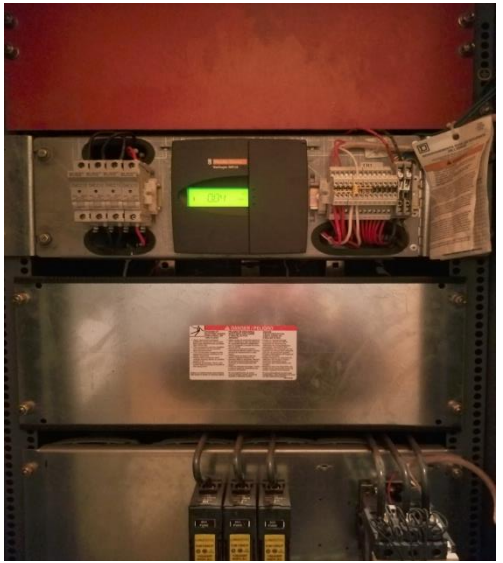
	SagFighter™ Solution	Flywheel UPS Solution
Estimated value of investment required for implementation of a solution for one (1) process line	**$ 235,000**	**$ 339,000**

Old facilities: Power Factor Correction Opportunties

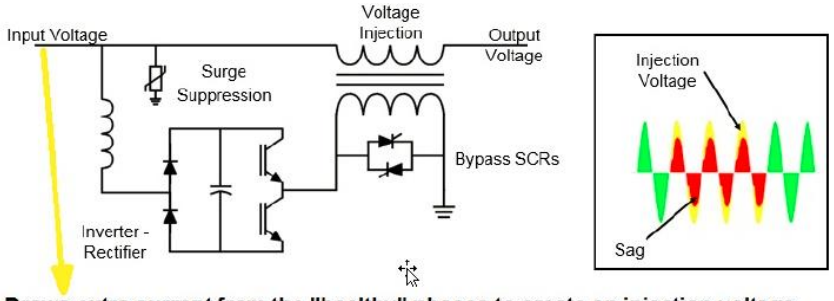
Electricity bills

Fixed capacitors should be removed.

Automatic capacitor banks: detuned & maintained.



Solution: Sag fighter and UPS



Draws extra current from the "healthy" phases to create an injection voltage

Figure 3 : SagFighter sketch

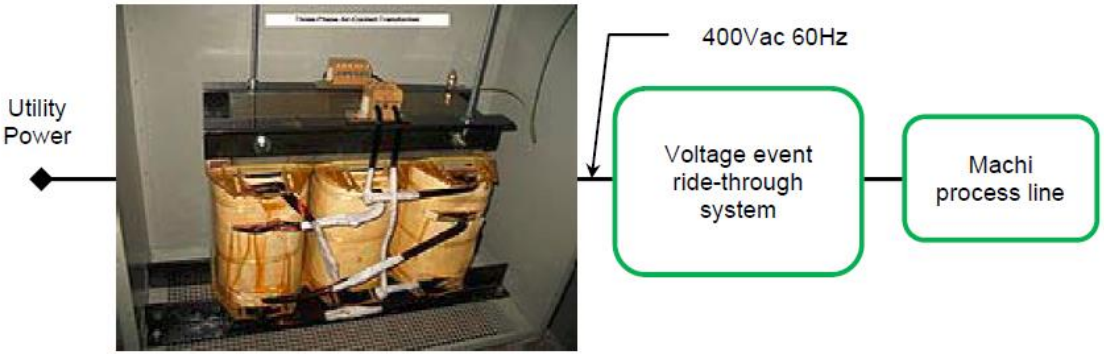
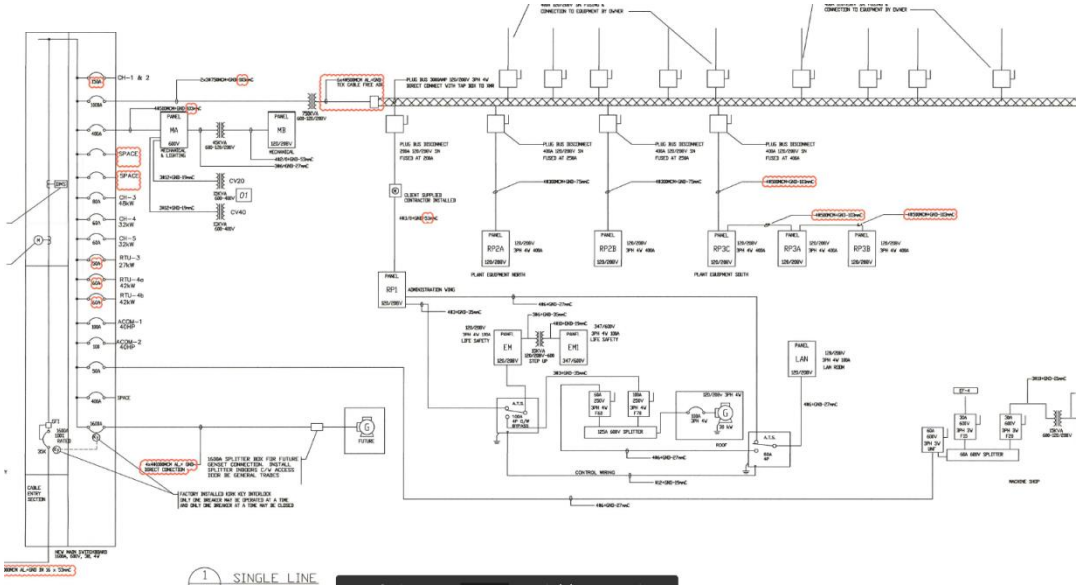


Figure 2 : positioning of the "Voltage Event Ride-Through System"

Voltage Power Quality Case Study: Sure Volt

- Pharmaceutical company with highly senstive electronics.
- End of a utility line, suffering voltage drops during peak demand.
- Sensitive equipment goes offline, unplanned downtime

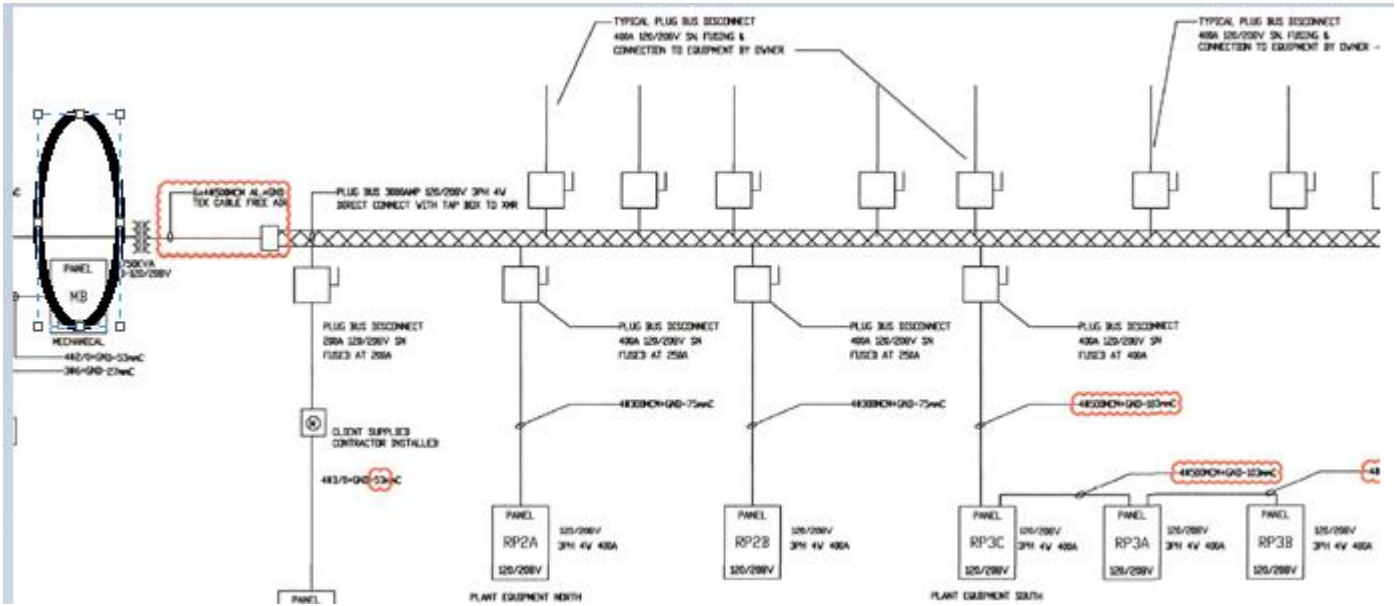


Data extracted from ION meter

- Lowest recorded voltage in past year: 75% of nominal voltage
- Recommended range: +-10% nominal voltage

Proposed solution: Sure-Volt

- 500kVA Sure-Volt proposed at artery where sensitive equipment is failing.
- Regulates voltage +-3%



PQ Audit Case 3: Industry with PME

- Industries prone to
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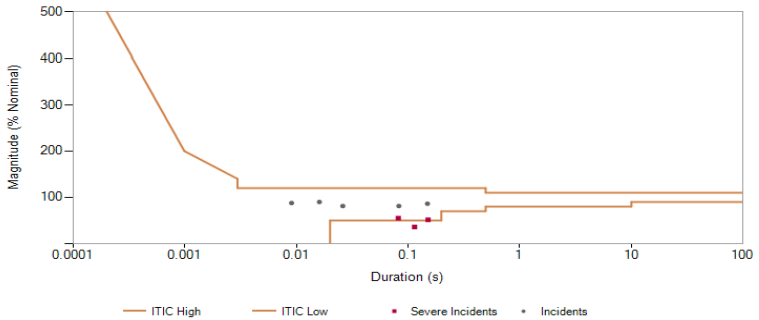
  - Electronics manufacturer
  - Water/waste water treatment plant



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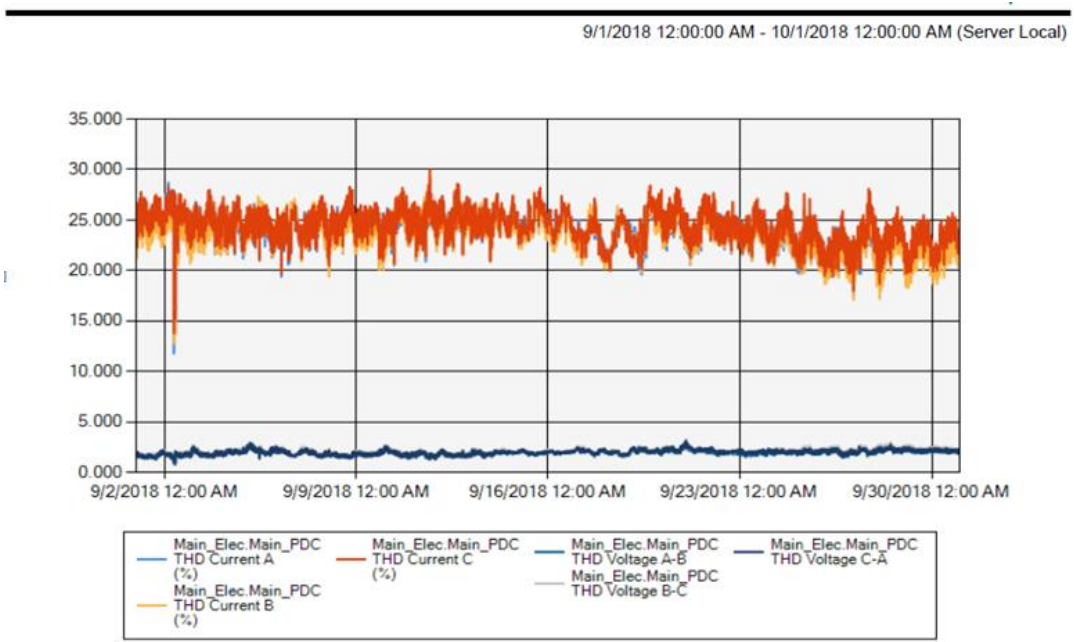
Case 4: Municipality with PME

- Water/Waster treatment plant
- High harmonics
- Existing capacitor bank



PQ Audit Case 5: Large industry with Power Advisor

Potential Issue: Excessive Voltage Harmonic Distortion Condition

Meltshop.EM03A

Device Type: 7330

Threshold: 3.00% THD

System Load Affected: 2,127,700.04 %

Comment: Excessive Voltage Harmonic Distortion Condition has been found for multiple measurements at this location. The most severe is: Voltage Total Harmonic Distortion Mean on Input V1 reached 42.04%. This indicates significant voltage waveform distortion. It would be useful to include phase voltages and currents to be logged.

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THD Voltage C-A mean	0.00 %	7.80%	0.00%	41.43%	----
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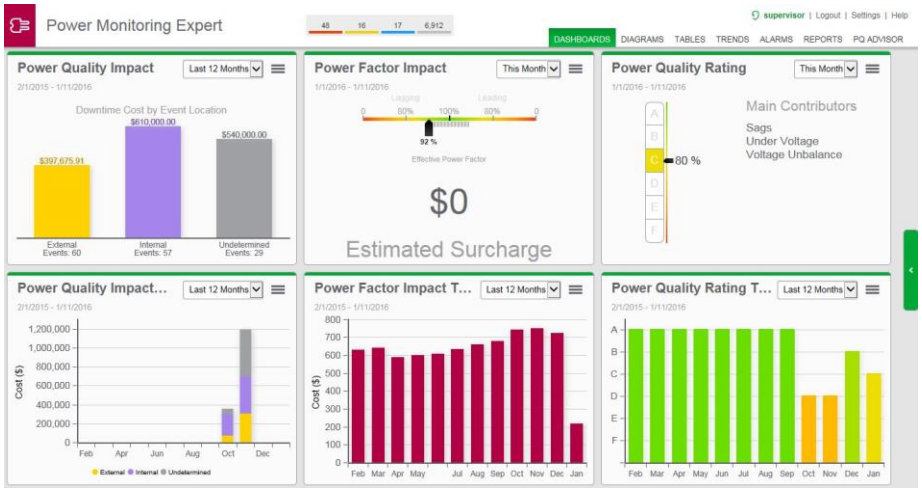
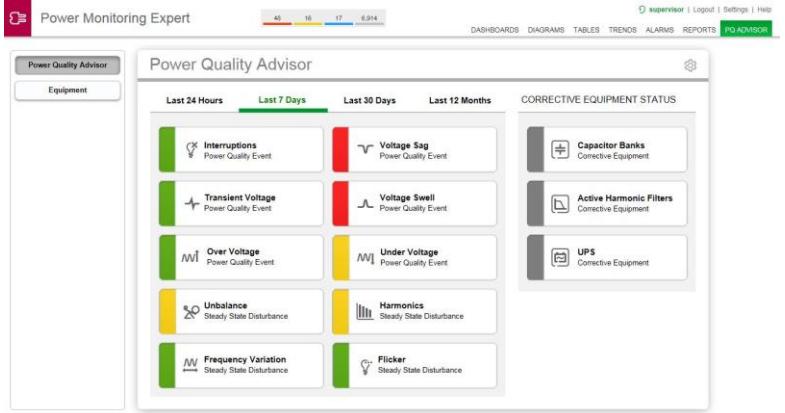
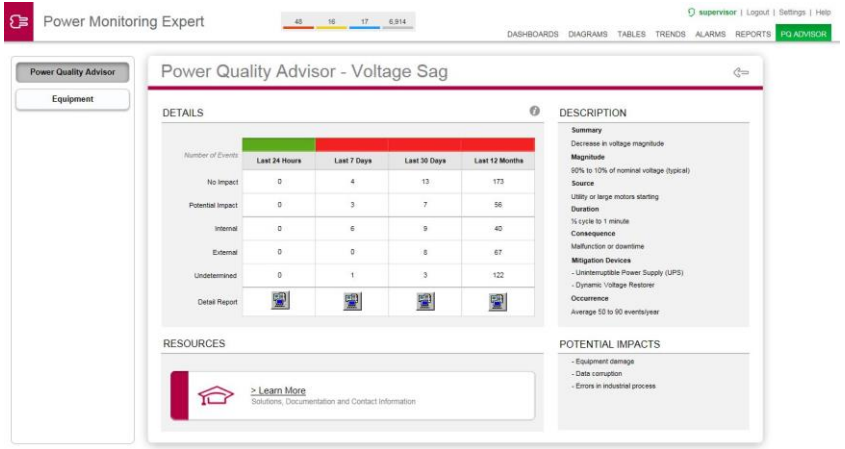
Power Advisor







- **Simple, meaningful power system analytics**
  - Understand business impact of poor power quality
  - View cost impact from low power factor
  - Monitor the evolution of electrical system health

Power management with Power Quality Performance

Power Quality Performance

Services
Audit, technical support & application services

Software
Software application specific to PQ in Industrial Plants

Hardware
Modular & scalable to fit customer needs & plant size

Plant Floor
From industrial loads to main incomer

Demand generation Directly from software

Power Quality Advisor Software Application

Metering / Comms / IEDs

Up to 300+ devices

Power Factor Correction

Up to 15 cap. banks

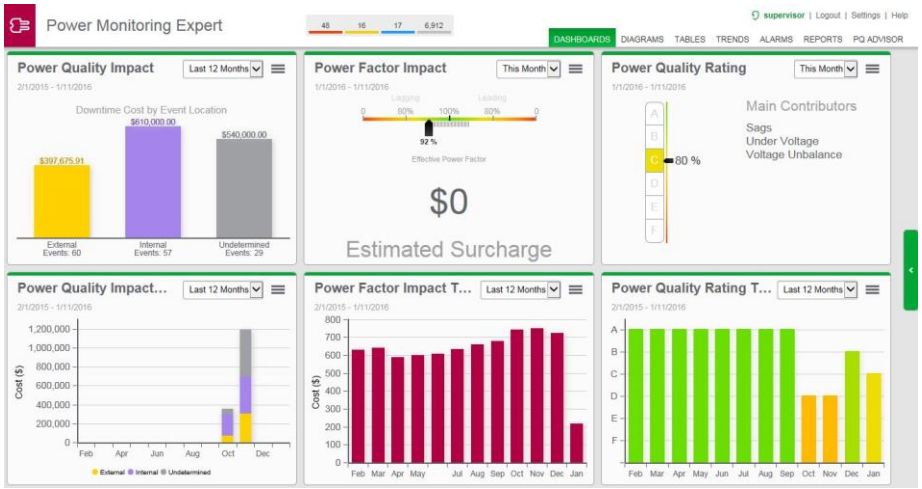
Harmonic Mitigation

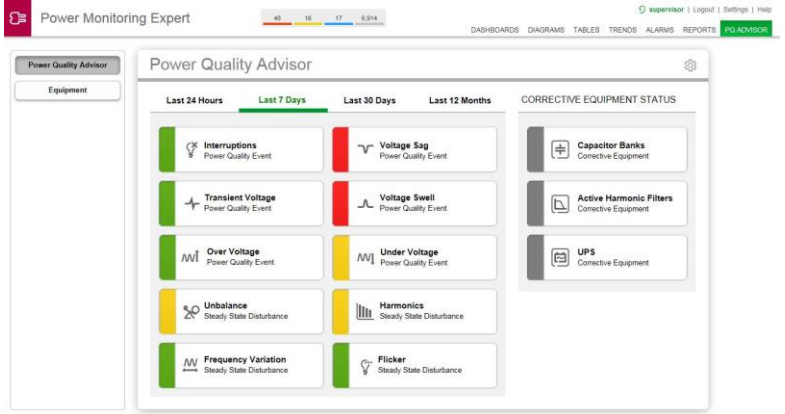
1-5 harmonic filters

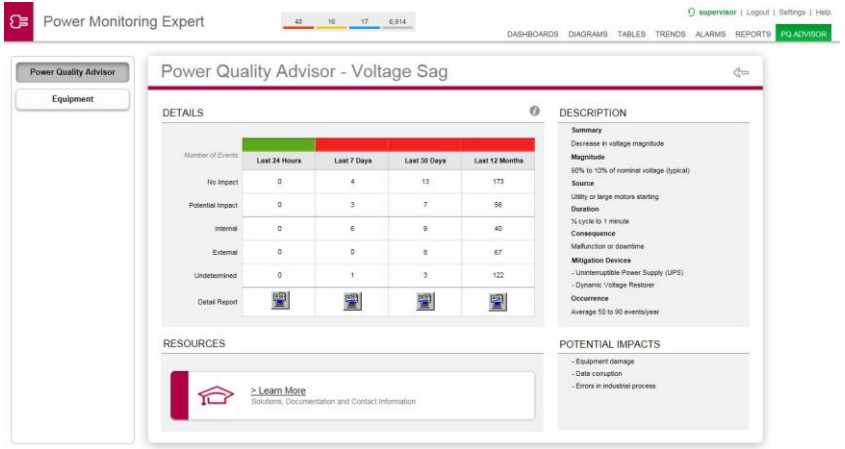
Voltage Sag Mitigation

1-5 Uninterruptible Power Supply

Power Quality Performance







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