Power Quality Overview

Understanding power disturbance analysis

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Agenda

- Introduction to Power Quality
- Power Quality Advisor – Energy Management Software
- Case Study: Active Harmonic Filter in healthcare facility
- Case Study: Voltage Sags
- Case Study: Voltage Regulation

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Different types of Power Quality problems

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

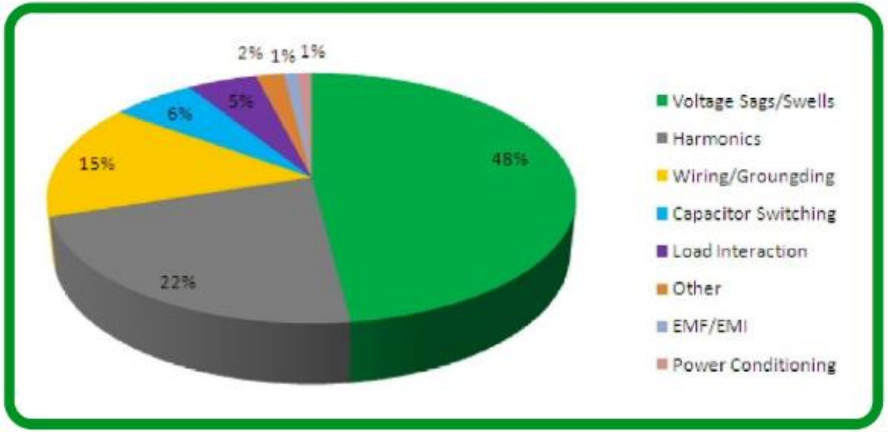
- Nominal Voltage on all 3 phases
- Nominal frequency (60.00Hz)
- Waveforms are perfectly sinusoidal
- Symmetry in all phases

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

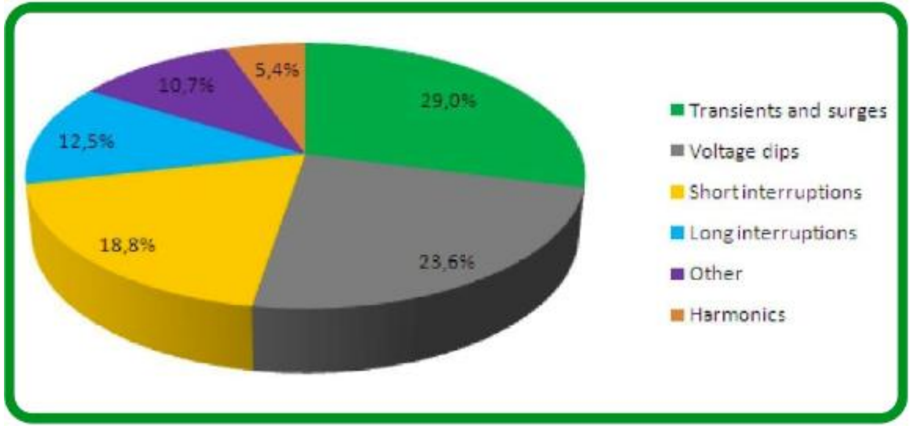
Disturbance category	Waveform	Effects	Possible causes
Transients		Equipment malfunction and damage	Lightning or switching of inductive / capacitive loads
Interruption		Downtime, equipment damage, loss of data possible	Utility faults, equipment failure, breaker tripping
Sag		Downtime, system halts, data 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...)

Power Quality problems are a major source of equipment failure and unplanned downtime

Power Quality problems are the root cause of 30-40% of unplanned downtime



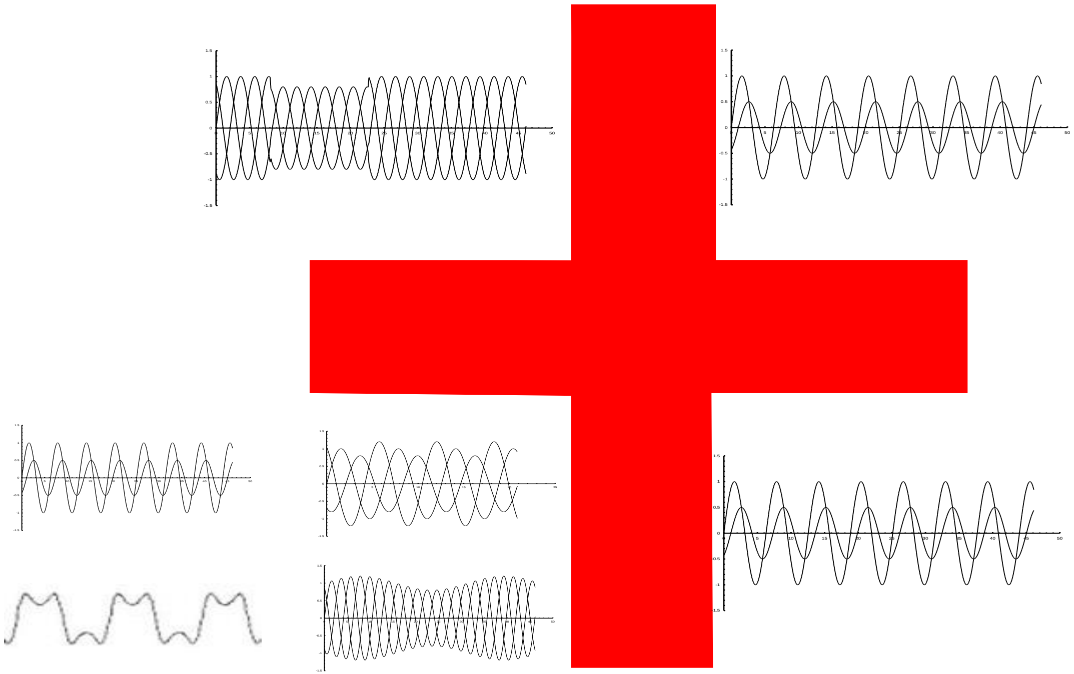
Most common power quality issues (US)



Most common power quality issues (EU)

Companies get sued & people get fired when this stuff happens

Different remedies for different Power Quality problems



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

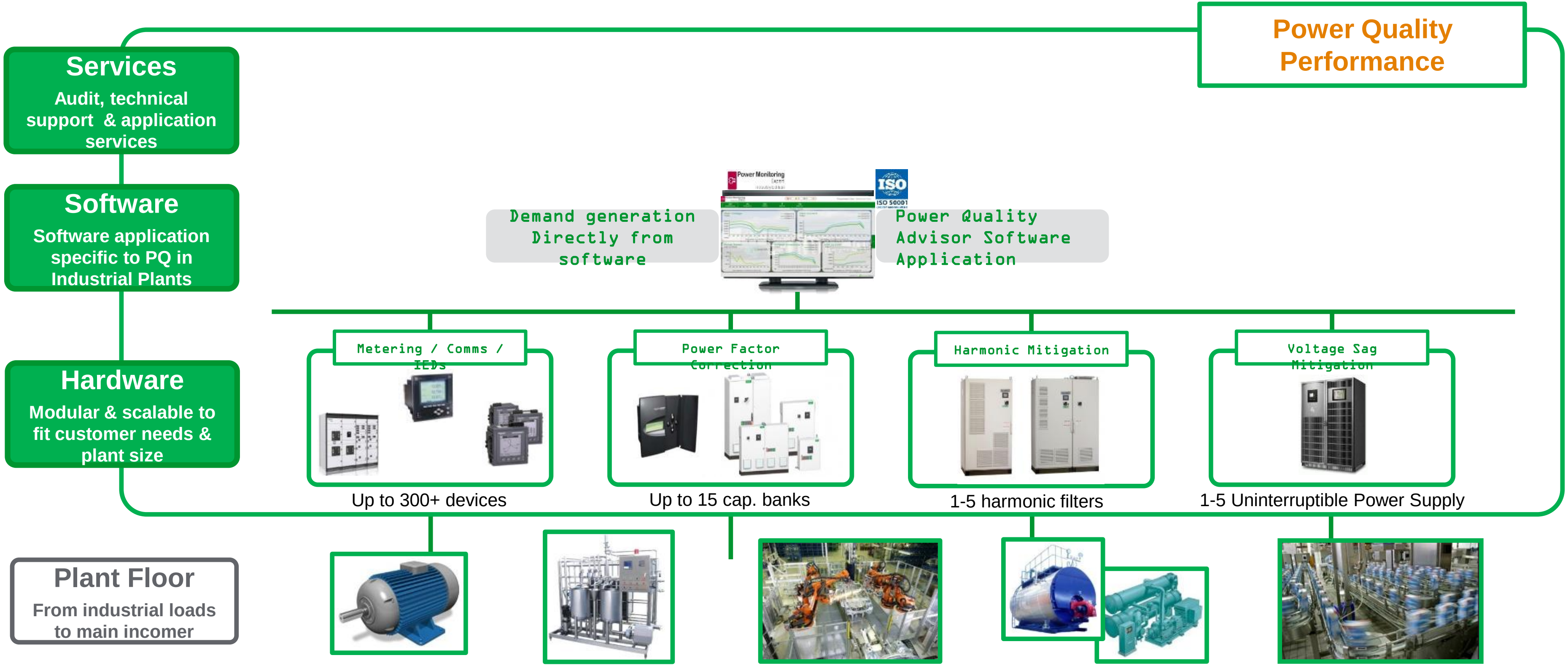
Robust, flexible software platform architectures
Real-time energy consumption monitoring
Dynamic control interfaces
Real-time and historical power quality analysis

Act

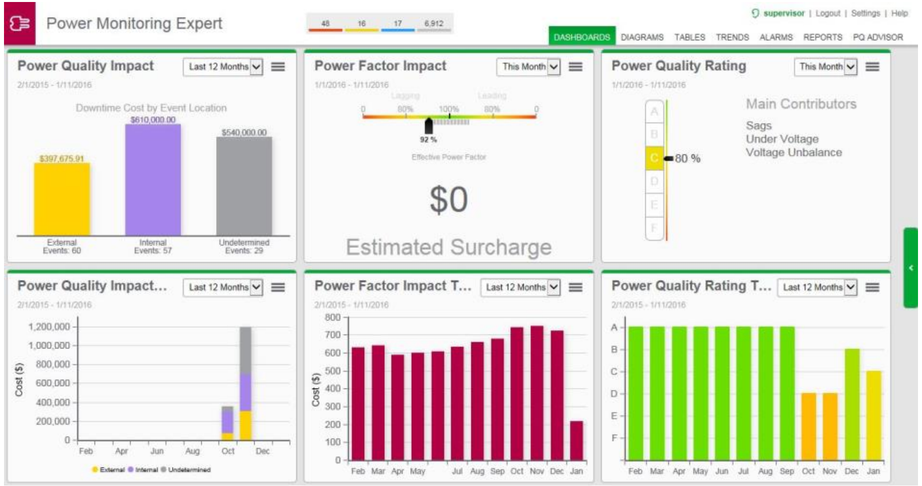
Make timelier, intelligent decisions based on valid, actionable information

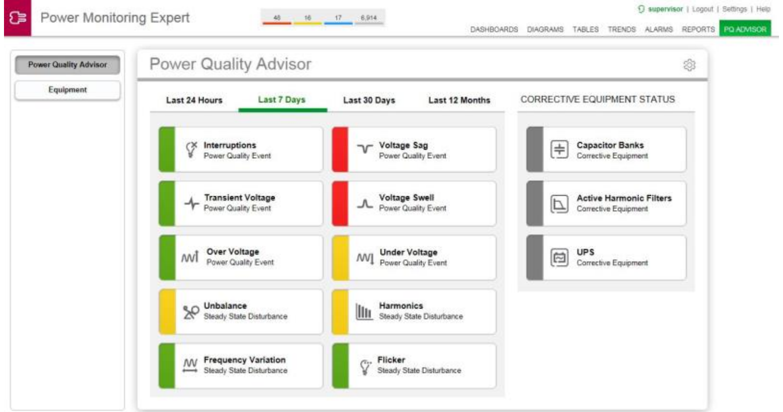
Increased energy efficiency and cost savings
Maximize electrical network reliability and availability
Optimize electrical asset performance

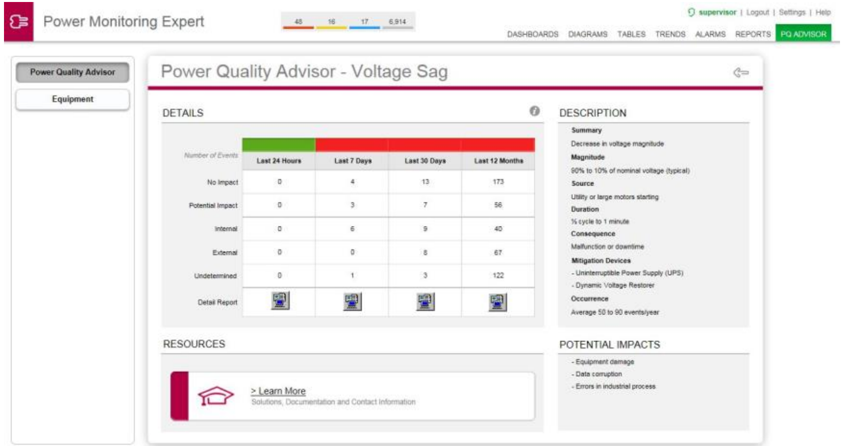
Power management with Power Quality Performance



Power Quality Performance







- **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

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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

Existing harmonic standards

Standards relative to **installations**:

IEC 61000 - a series of standards dealing with power quality issues.

- IEC 61000-2-2 harmonic levels at public low-voltage power supply systems
- IEC 61000-2-4 harmonic levels at LV and MV industrial installations
- IEC 61000-3-6 harmonic levels at MV and HV installations

IEEE 519 – 2014 : requirements on harmonic control in electrical installations (NEMA)

Adjustments at country level may exist (ex. Engineering Recommendation G5/4)

Standards relative to **individual equipment** :

IEC 61000

IEC 61000-3-2	low voltage equipment with rated current under 16A
IEC 61000-3-12	low voltage equipment with rated current higher than 16A and lower than 75A

IEC 61800-3 specific standard for variable speed drives

Harmonic Mitigation Solutions

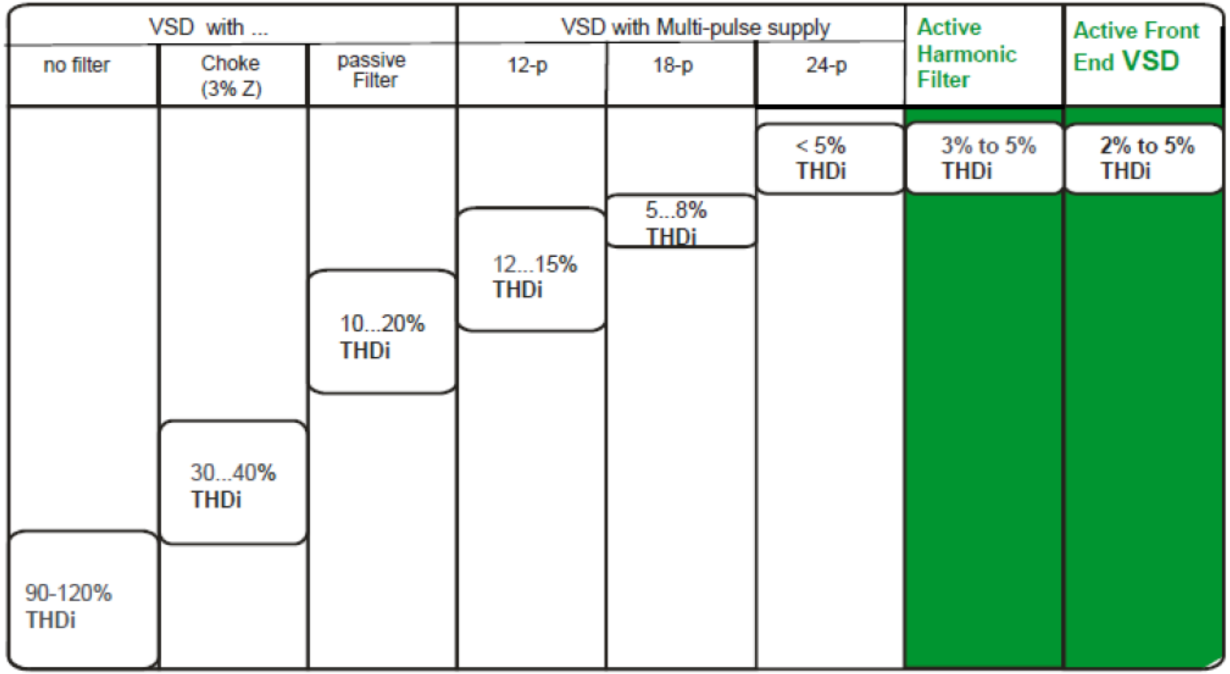

Figure 1 THDi levels achieved with various harmonic mitigation methods

Active Harmonic Filter installation in existing hospital

Case Study

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Success story: Active Harmonic Filter turnkey project

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.

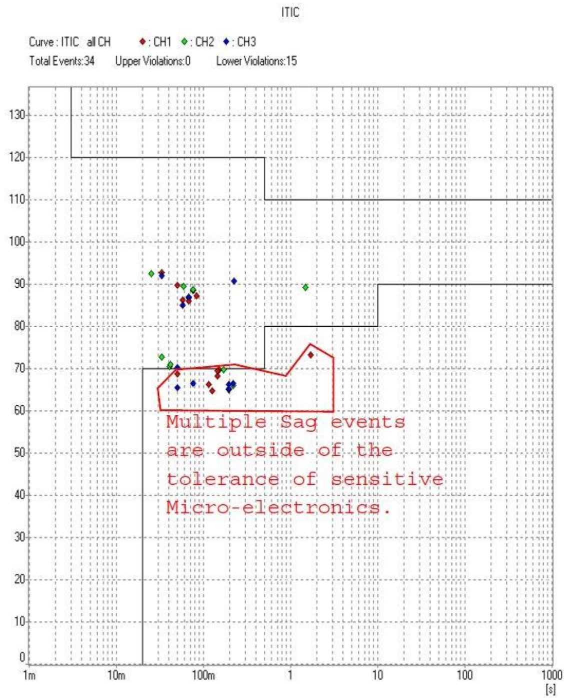
The Solution

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.

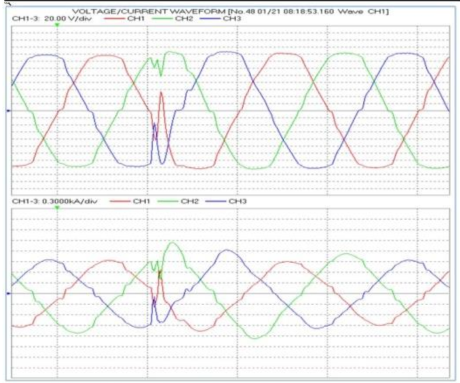
Power Quality disturbances

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



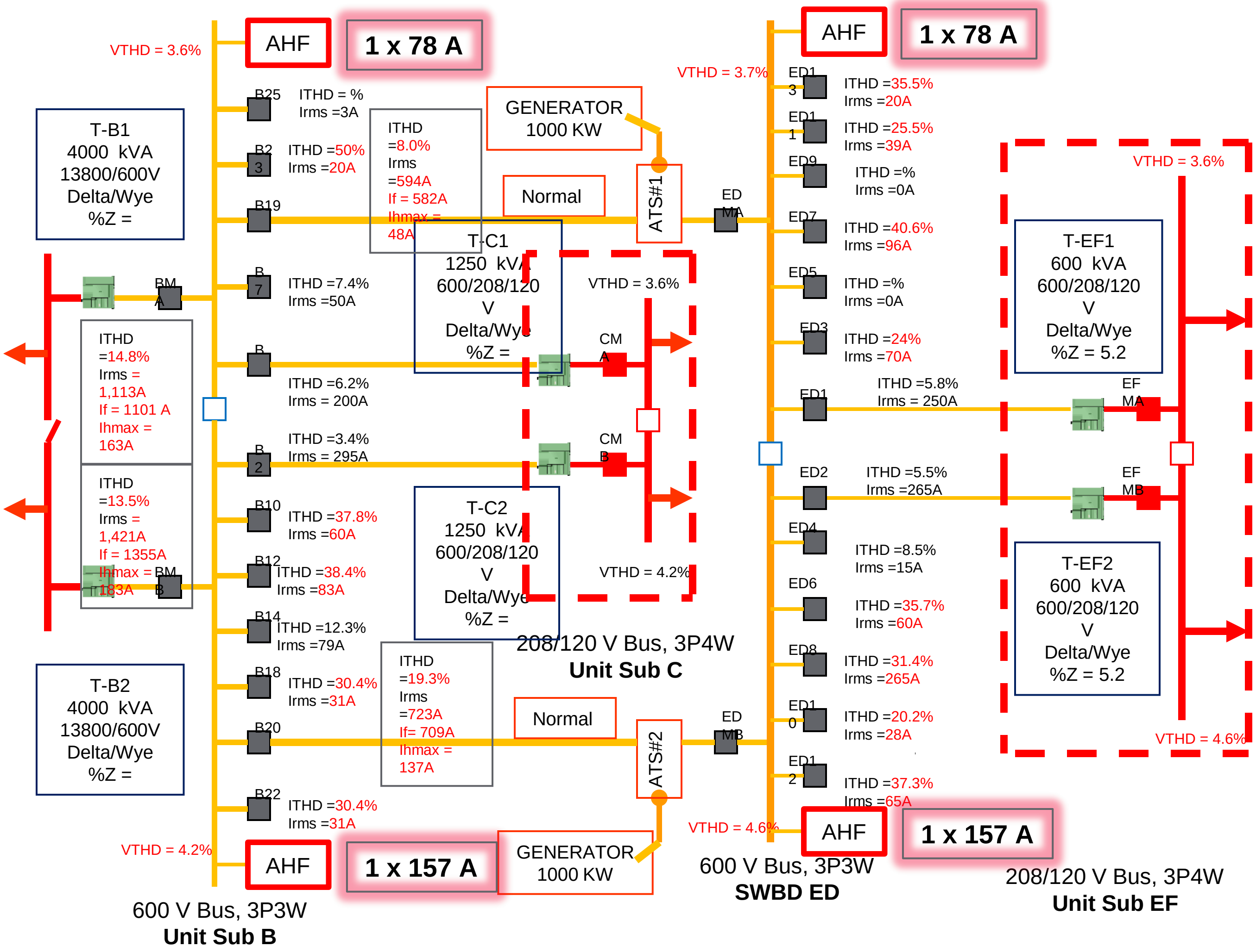
POWER		VOLTAGE		CURRENT	
Freq	57.813 Hz				
P1	0.0473MW	U1	116.48 V	I1	0.4268kA
P2	0.0611MW	U2	115.84 V	I2	0.5341kA
P3	0.0521MW	U3	115.70 V	I3	0.4640kA
Psum	0.1606MW	THD-U1	3.25 %	THD-I1	10.12 %
S1	0.0497MVA	THD-U2	6.79 %	THD-I2	10.71 %
S2	0.0619MVA	THD-U3	7.41 %	THD-I3	12.48 %
S3	0.0537MVA	Upk+1	157.57 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	0.7303kA
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	-162.38 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	0.6529kA
				Iunb	6.18 %



Possible solutions

Solution	Pros	Cons	Mitigates Voltage Distortion on Dialysis Machine	Mitigates Voltage Sag on Dialysis Machine	Mitigates Multiple Zero Crossings on Dialysis Machine	Estimate	Recommended
1. Active Harmonic Filter	Will solve Vthd problem in the entire distribution system	Requires further analysis to size correctly	✓	✗	✗	TBD	✓
2. SagFighter	Protects the Dialysis Machines	No effect on PQ problems	✗	✓	✓	64,000$ + installation	✓
3. UPS	Protects the Dialysis Machines	No effect on PQ problems	✓	✓	✓	120,000$ + installation	✗


VTHD = 3.6%
AHF
1 x 78 A
T-B1
4000 kVA
13800/600V
Delta/Wye
%Z =
B25
ITHD = %
Irms =3A
B23
ITHD =50%
Irms =20A
ITHD
=8.0%
Irms
=594A
If = 582A
Ihmax =
48A
GENERATOR
1000 KW
Normal
ATS#1
B19
BMA
B7
ITHD =7.4%
Irms =50A
T-C1
1250 kVA
600/208/120
V
Delta/Wye
%Z =
VTHD = 3.6%
CMA
ITHD
=14.8%
Irms =
1,113A
If = 1101 A
Ihmax =
163A
B
ITHD =6.2%
Irms = 200A
B2
ITHD =3.4%
Irms = 295A
CMB
ITHD
=13.5%
Irms =
1,421A
If = 1355A
Ihmax =
183A
BMB
B10
ITHD =37.8%
Irms =60A
T-C2
1250 kVA
600/208/120
V
Delta/Wye
%Z =
B12
ITHD =38.4%
Irms =83A
VTHD = 4.2%
B14
ITHD =12.3%
Irms =79A
208/120 V Bus, 3P4W
Unit Sub C
T-B2
4000 kVA
13800/600V
Delta/Wye
%Z =
B18
ITHD =30.4%
Irms =31A
ITHD
=19.3%
Irms
=723A
If= 709A
Ihmax =
137A
Normal
ATS#2
B20
B22
ITHD =30.4%
Irms =31A
VTHD = 4.2%
AHF
1 x 157 A
GENERATOR
1000 KW
600 V Bus, 3P3W
Unit Sub B
AHF
1 x 78 A
VTHD = 3.7%
ED13
ITHD =35.5%
Irms =20A
ED11
ITHD =25.5%
Irms =39A
ED9
ITHD =%
Irms =0A
EDMA
ED7
ITHD =40.6%
Irms =96A
ED5
ITHD =%
Irms =0A
ED3
ITHD =24%
Irms =70A
ED1
ITHD =5.8%
Irms = 250A
ED2
ITHD =5.5%
Irms =265A
ED4
ITHD =8.5%
Irms =15A
ED6
ITHD =35.7%
Irms =60A
ED8
ITHD =31.4%
Irms =265A
ED10
ITHD =20.2%
Irms =28A
EDMB
ED12
ITHD =37.3%
Irms =65A
VTHD = 4.6%
AHF
1 x 157 A
600 V Bus, 3P3W
SWBD ED
VTHD = 3.6%
T-EF1
600 kVA
600/208/120
V
Delta/Wye
%Z = 5.2
EFMA
EFMB
T-EF2
600 kVA
600/208/120
V
Delta/Wye
%Z = 5.2
VTHD = 4.6%
208/120 V Bus, 3P4W
Unit Sub EF

Our Value Proposal

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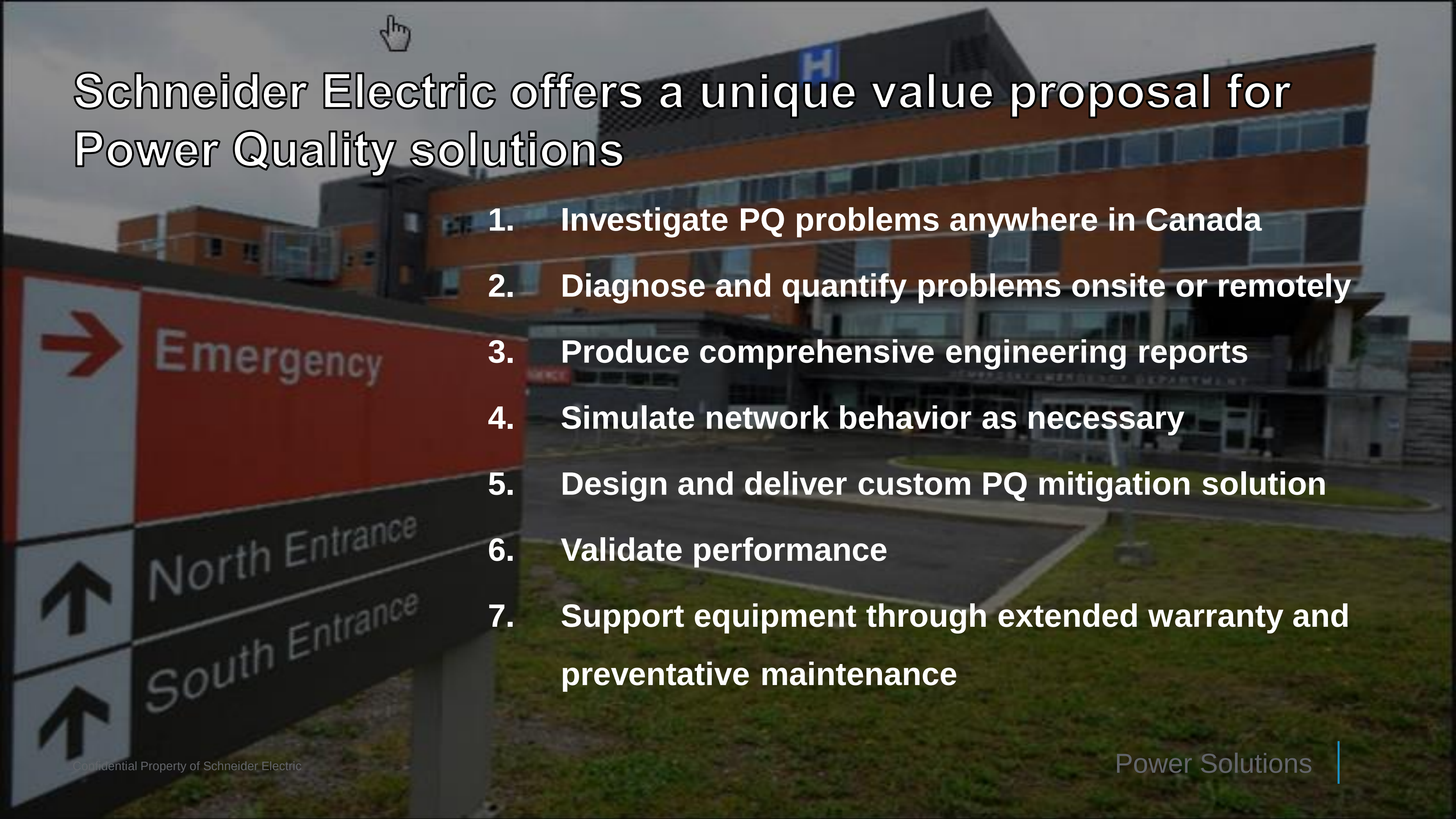
Schneider Electric offers a unique value proposal for Power Quality solutions

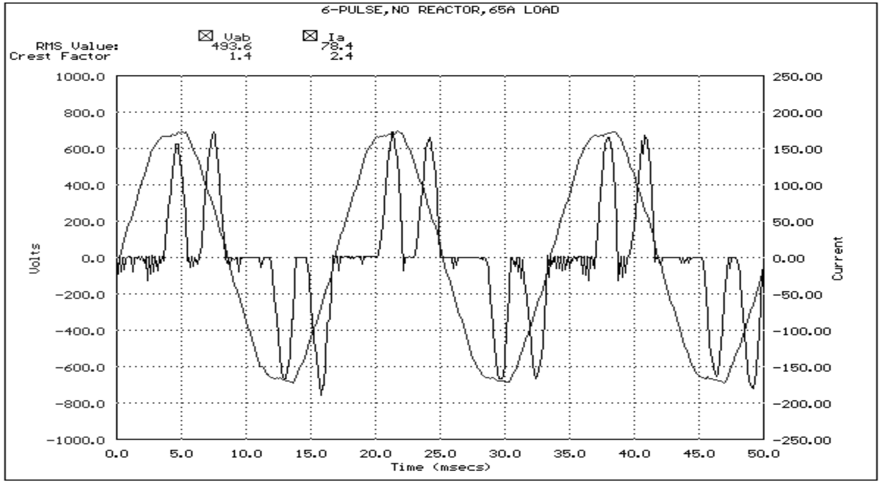


1. Investigate PQ problems anywhere in Canada
2. Diagnose and quantify problems onsite or remotely
3. Produce comprehensive engineering reports
4. Simulate network behavior as necessary
5. Design and deliver custom PQ mitigation solution
6. Validate performance
7. Support equipment through extended warranty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

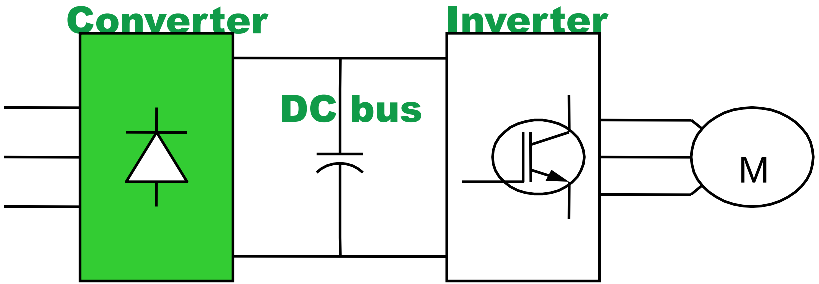
PWM VFD without 3% Line Reactance

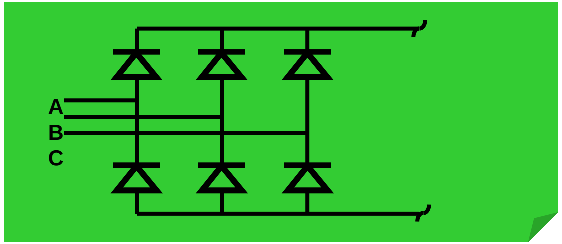
Current Distortion:

THDi ≈ 90%



Basic PWM VSD





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					

IEEE 519-2014 Table 2

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

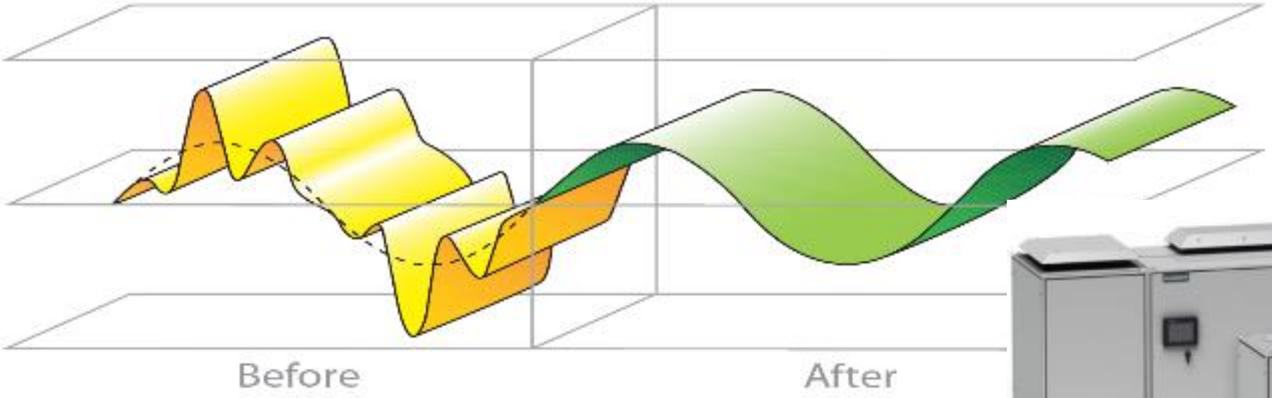
Equivalent installed impedance:	3.00	%
Selection adjustment factor according to installed impedance:	1.20	
System Short Circuit Ratio (ShCR) @ selected PCC:	39.8	:1

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	

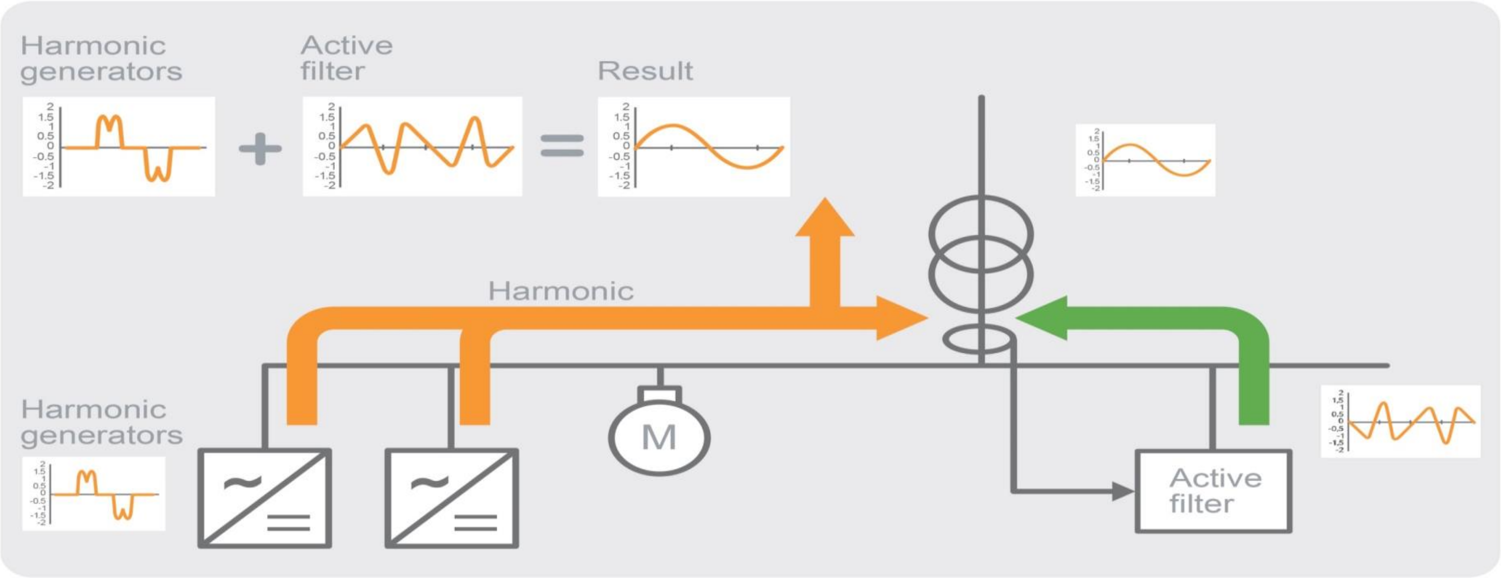
AccuSine PCS+



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)

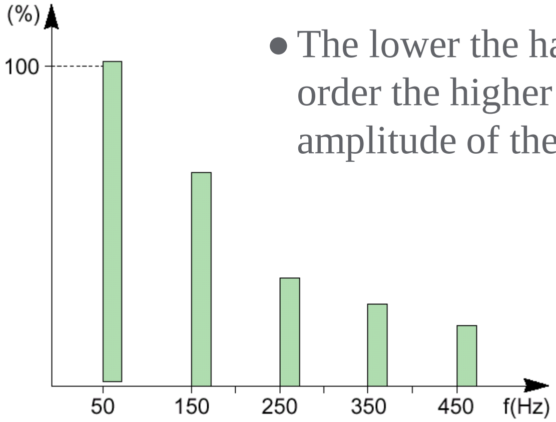
AccuSine PCS+ theory of operation

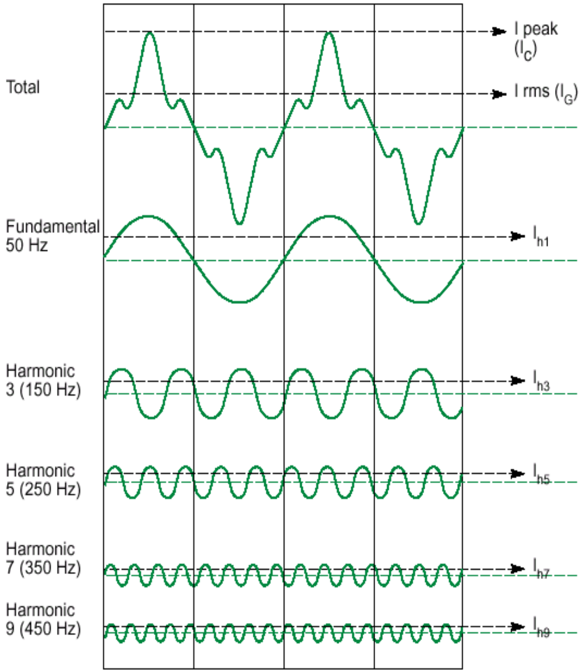
- AccuSine PLUS is a power electronic converter utilizing digital logic to inject corrective currents into a 3-phase power-source. These injected currents will compensate for existing harmonic currents from the 2nd to the 50th harmonic order drawn by non-linear loads connected to that grid.



Harmonics:Fundamentals (cont.)

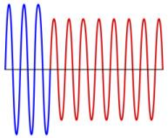
- Power source supplies the current the loads require for proper operation
- Harmonic current (Ih) is produced when an electrical device uses (draws) current in a non-sinusoidal manner
- The lower the harmonic order the higher the amplitude of the current





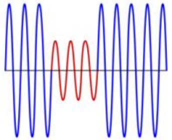
Voltage Problems – Basics

Chronic Voltage Problems



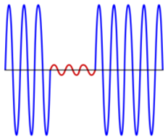
- Voltage outside ±10% for > 60 seconds

Voltage Sag



- Voltage < 90% for ½ cycle to 1 minute

Interruption



- Voltage < 10% for >3 cycles

A Sub-Cycle problem

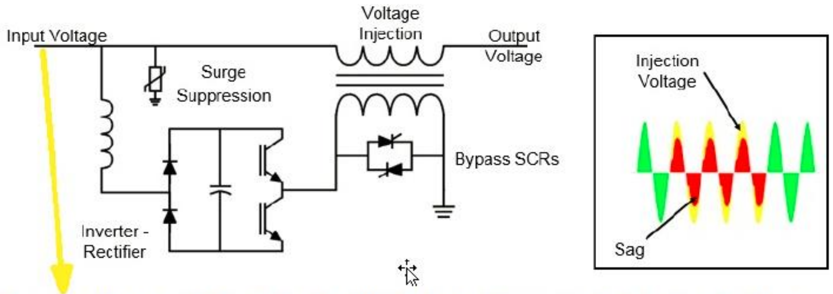
Voltage Power Quality Case Study: Sag Fighter

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 meters installed on site.

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

Solution: Sag fighter and UPS



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

Figure 3 : SagFighter sketch

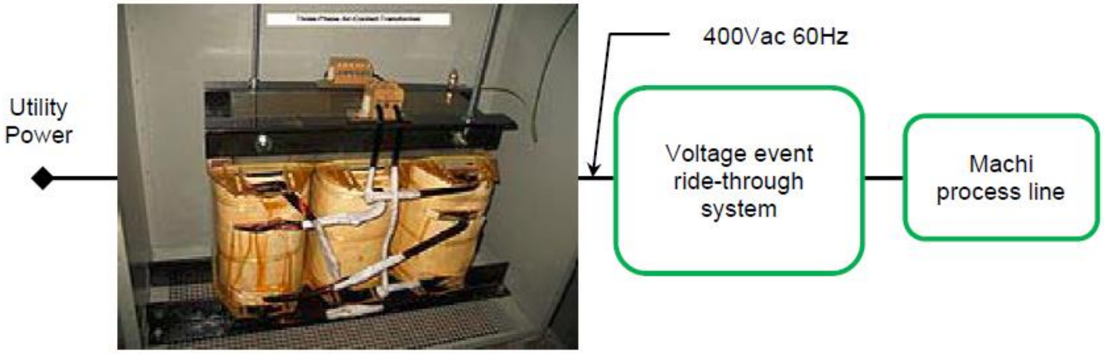
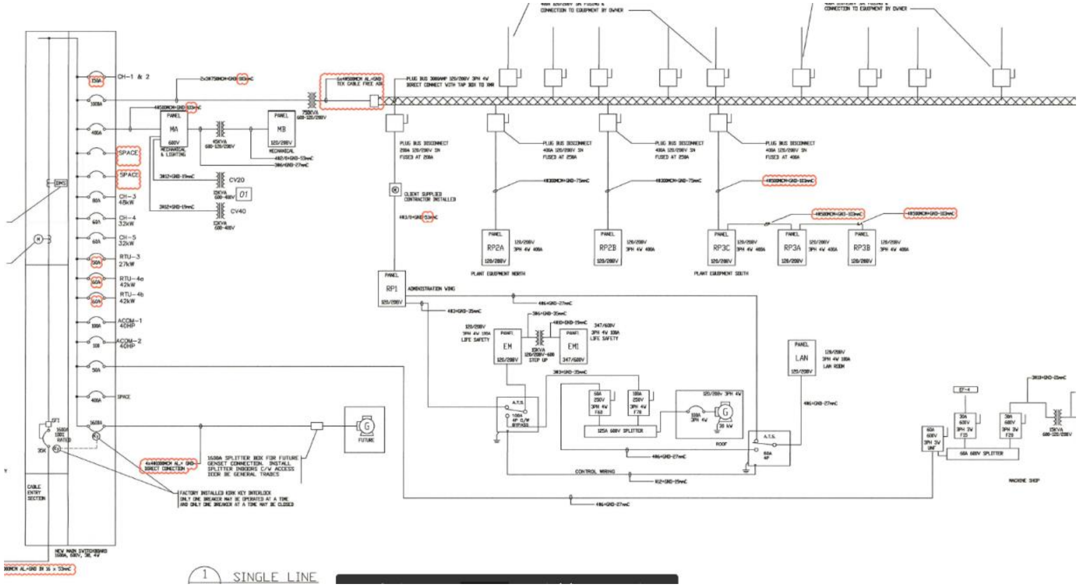


Figure 2 : positioning of the "Voltage Event Ride-Through System"

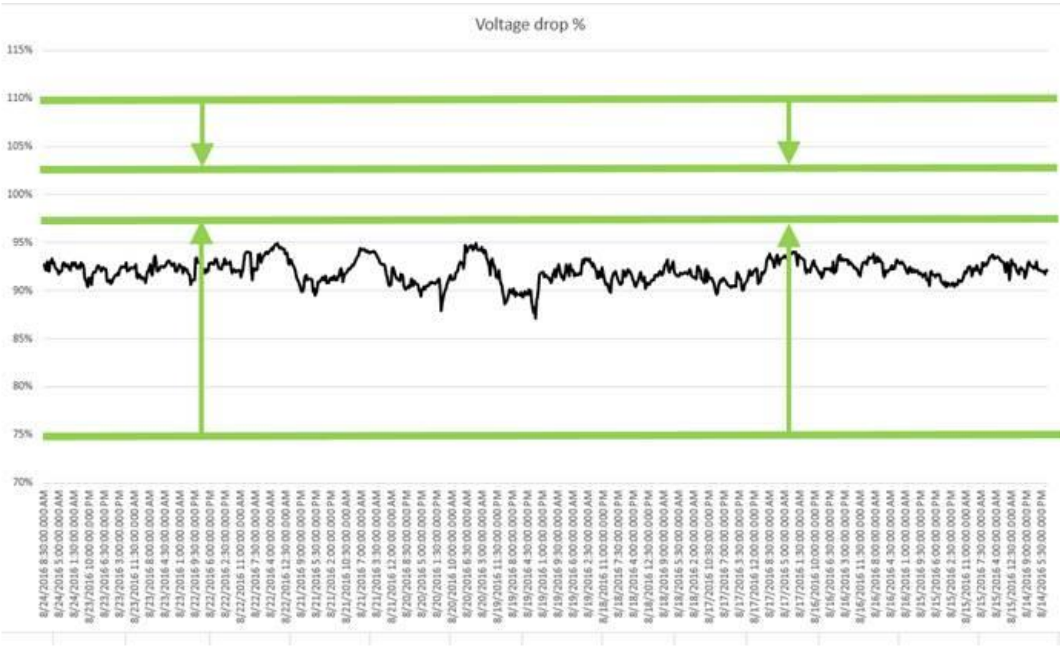
Voltage Power Quality Case Study: Sure Volt

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



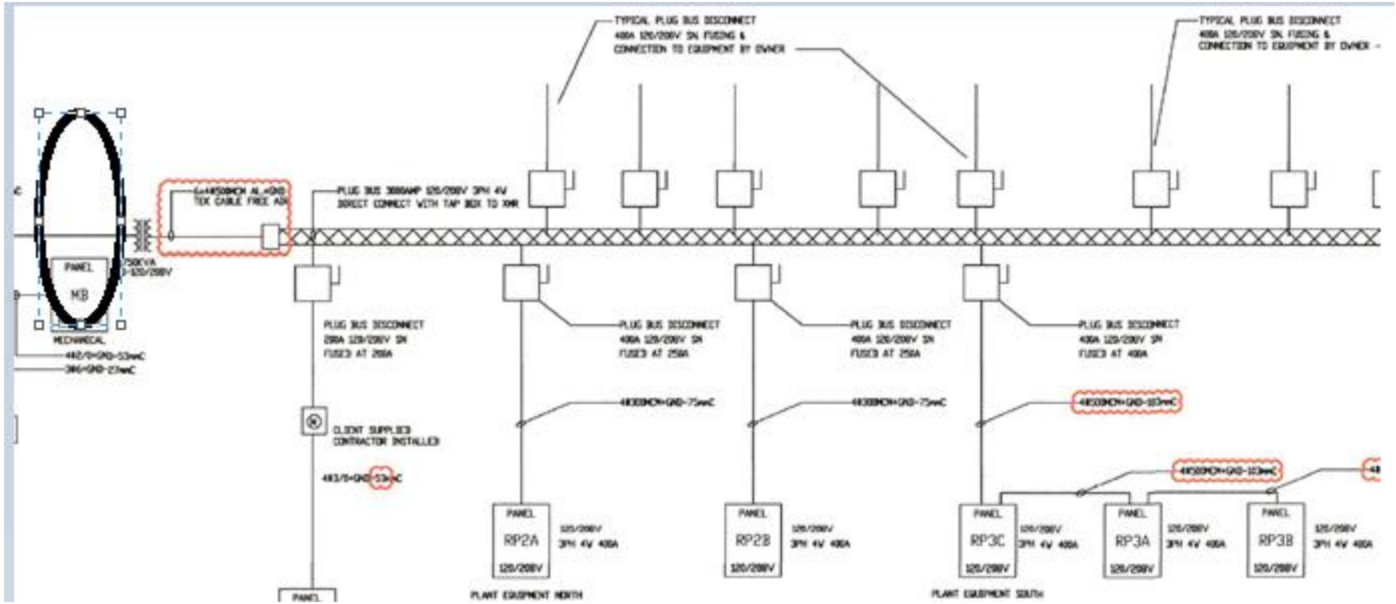
Data extracted from ION meter

- 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%



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