THE IMPACT OF POOR POWER QUALITY

How higher energy-efficiency can lead to lower productivity and higher operating costs

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Schneider Electric

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Agenda

- Understanding the root of Power Quality Problems
- Common types of Power Quality problems and business impact
- Problem solving methodology
- Solutions to Power Quality problems

UNDERSTANDING THE ROOT OF POWER QUALITY PROBLEMS

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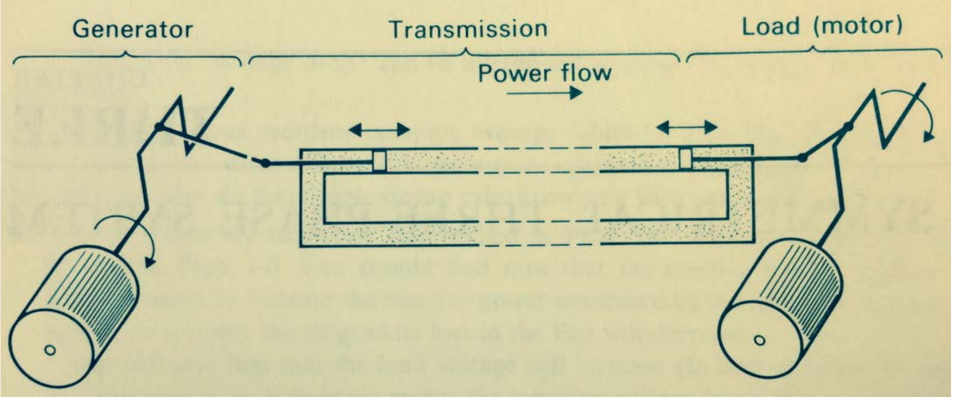
INTRODUCTION

Understanding the root of Power Quality problems

- Our Electrical Power System is a complex system of generating stations and loads
- Our Electrical Power System (also known as the grid) was designed to provide smooth power through three phase Alternating Current (AC)

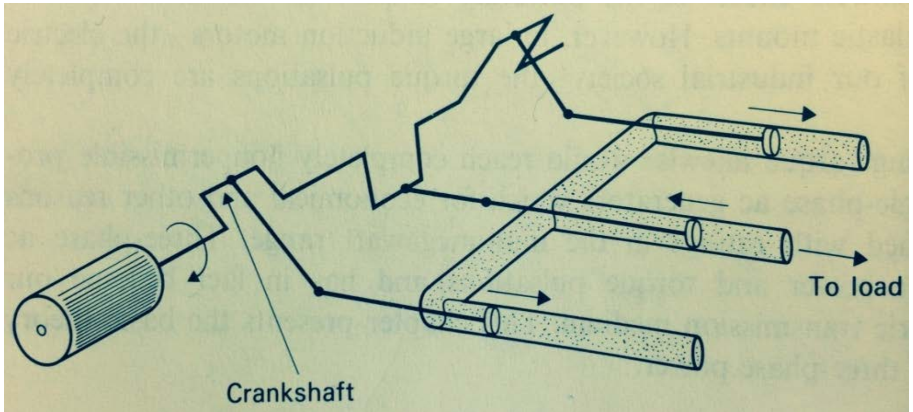


Single-phase Hydraulic system

- The torque is not constant throughout the rotation of the crankshaft

Three-phase Hydraulic system

- The torque is constant throughout the rotation of the crankshaft if the flow is "balanced" and "smooth" in all three phases
- Loads which consume in an unsmooth way introduce jerky flow and pressure



Understanding the root of Power Quality problems

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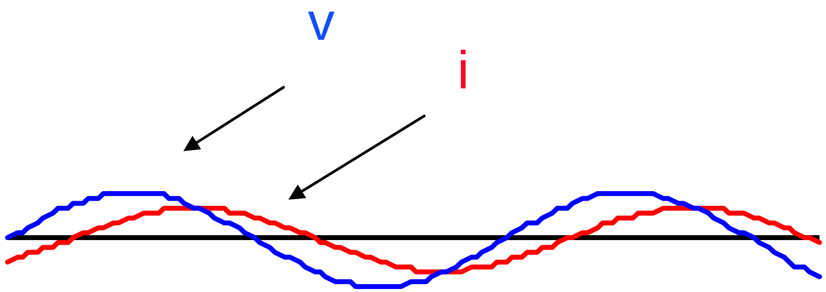
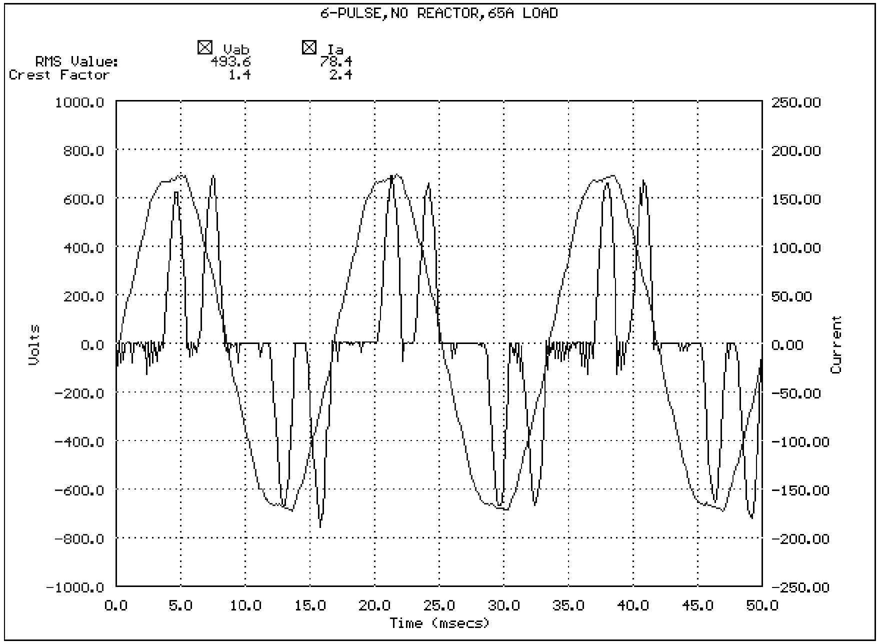
Linear Load



Non-Linear Load



Power Quality – A new Problem?

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In the past, Power Quality problems were reserved for large industrial users

- Power Quality problems have existed since the early days of the Electrical Power System
- In the early days, many utilities were notorious for having serious variations in the voltage they supplied to their customers
- By the mid 20^{th} century, most utilities provided sufficient and stable power and few customers had Power Quality issues.

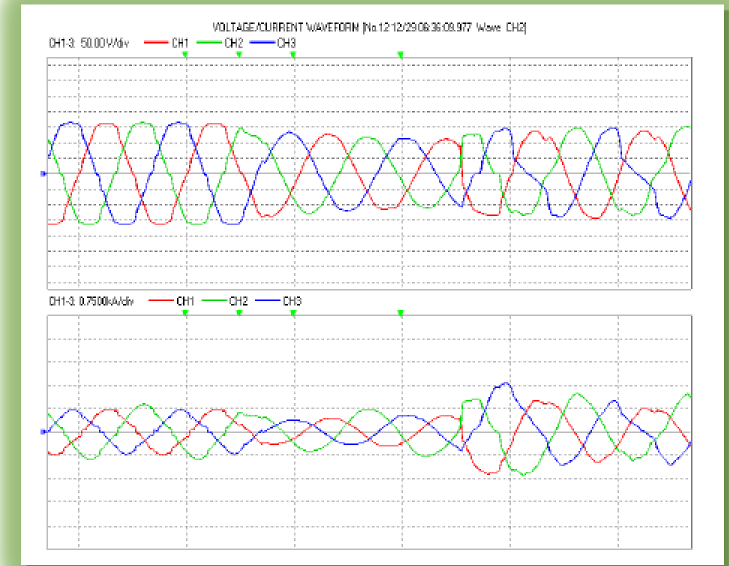
Today, Power Quality is becoming everyone's problem

- Until the advent of semiconductors and microcomputers, loads were "Linear" meaning the power they draw from the grid is constant and smooth
- In order to consume less energy, we have developed equipment which draws less energy but draws it in an **intermittent/jerky** manner.
- Today, generating capacity has been outpaced by energy demand and everyone is adding energy efficient devices to the grid
- Renewable Energy is adding to the problem by adding generation with short term variations
- The grid is not necessarily going to collapse, but the power is not always smooth

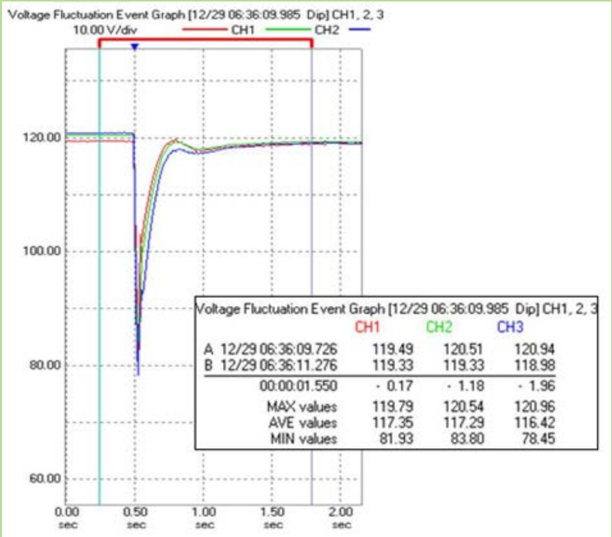
Examples of Voltage anomalies

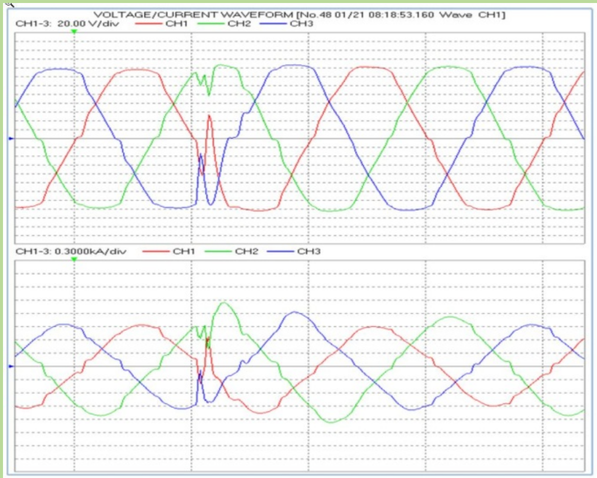
POWER		VOLTAGE		CURRENT	
Freq	59.968 Hz				
P1	0.0728MW	U1	119.09 V	I1	0.6225kA
P2	0.0872MW	U2	120.17 V	I2	0.7303kA
P3	0.0717MW	U3	120.51 V	I3	0.6059kA
Psum	0.2317MW	THD-U1	4.78 %	THD-I1	7.94 %
S1	0.0741MVA	THD-U2	4.72 %	THD-I2	8.86 %
S2	0.0878MVA	THD-U3	4.70 %	THD-I3	8.51 %
S3	0.0730MVA	Upk+1	163.45 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 %

Voltage Distortion



Voltage Sag





Multiple Zero Crossings

Power Quality can be maintained and improved

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Thanks to technological innovation, a solution to most Power Quality problems has been developed

COMMON TYPES OF POWER QUALITY PROBLEMS AND BUSINESS IMPACT

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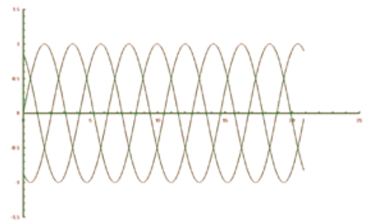
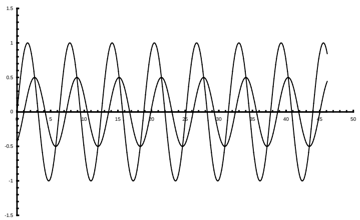
The ideal voltage supply does not exist

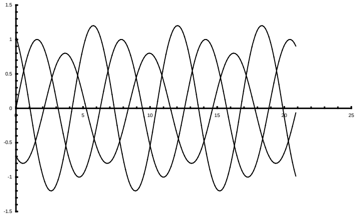


3-phase balanced

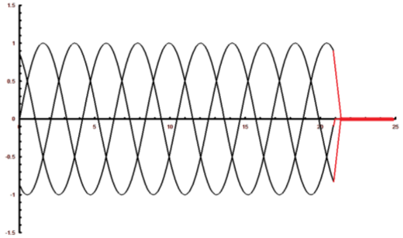


Power Factor

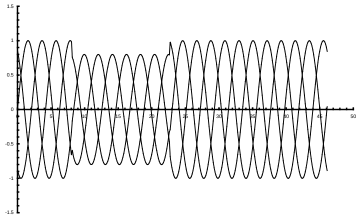
Harmonics



Phase unbalance

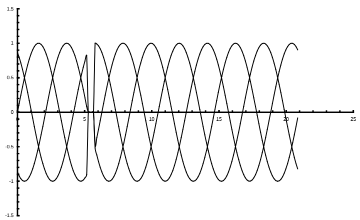


Blackout



Sags/swells

Overvoltage



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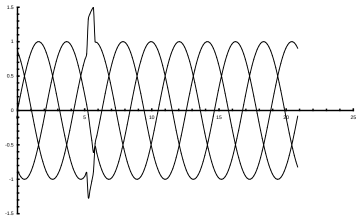
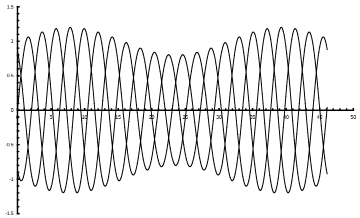


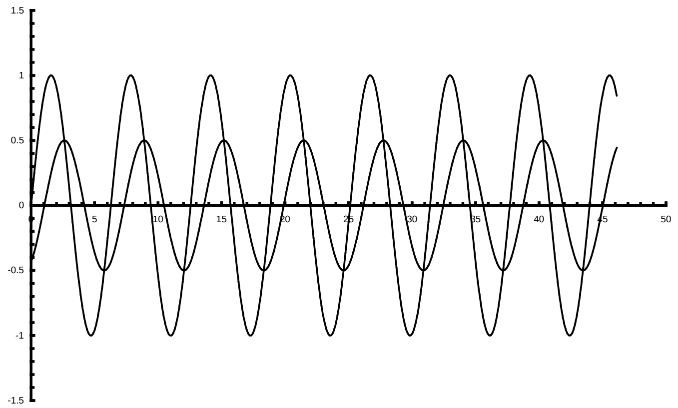
Transient (Spike)



Flicker

Noise

Power Factor Problem



Causes

- Large motors, Lightly loaded transformers

Signs/Symptoms

- Power Factor penalty on utility bills

Business Impact

- $$$ Penalty
- Wasted electrical capacity

Solution

- Capacitor Bank
- Inverter-based PFC system

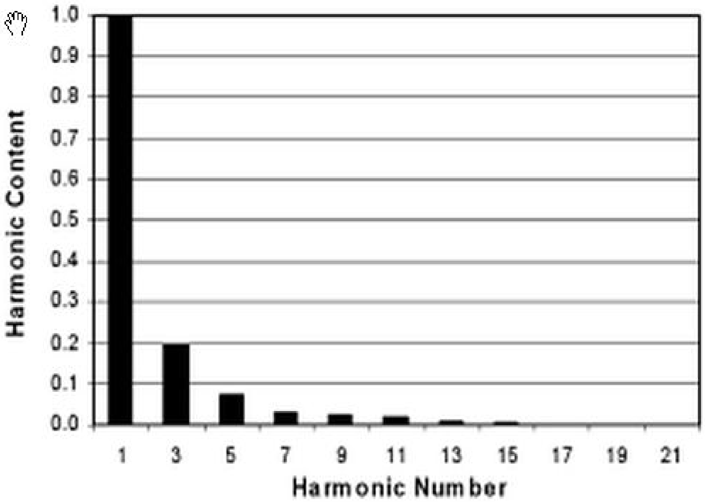
Poor Power Factor is an opportunity for savings

- Power Factor (PF) is a measure of how efficiently one draws power from the grid
- It is expressed as a percentage
  - 77% or 0.77
- Below 90% (or 95%), a billing penalty is applied by the utility
- If the current is “in phase” with the voltage, the PF=100%
- PF can be improved with AC capacitors

Be careful !!!

- By applying the wrong capacitor system, you can create other PQ problems: Resonance, Voltage Distortion, Voltage Transients

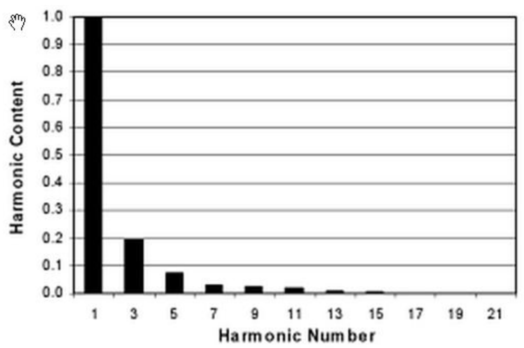
Harmonic Distortion Problem



Harmonic Distortion can affect current and voltage

- Harmonic Distortion exists because the waveform contains higher order frequencies (multiples of the 60Hz fundamental or "harmonics")
- Harmonic Distortion is the most common Power Quality problem today, excluding poor PF
- In the context of Electrical Power Systems, Harmonic Distortion is usually separated into:
  1. Current Distortion
  2. Voltage Distortion

Harmonic Distortion – Current



Harmonic Current Distortion is the most common form of electrical pollution in today's industrial, institutional and commercial facilities

Causes

- "Non-linear" loads: VFDs, electronic power supplies, Arc Furnaces, anything electronic, Most things energy efficient

Signs/Symptoms

- Transformers/cables overheating
- Nuisance tripping of circuit breakers
- Fuses blowing
- Voltage Distortion
- Capacitors overheating

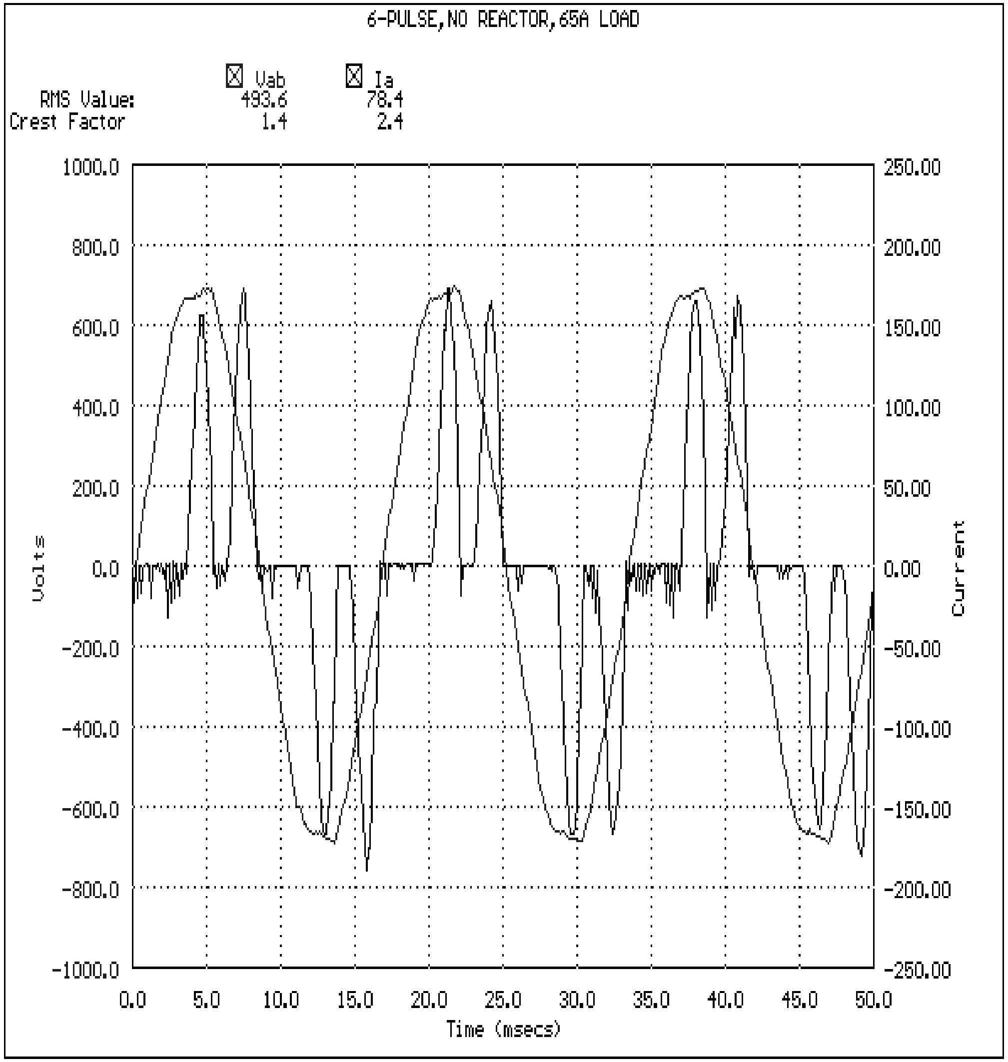
Business Impact

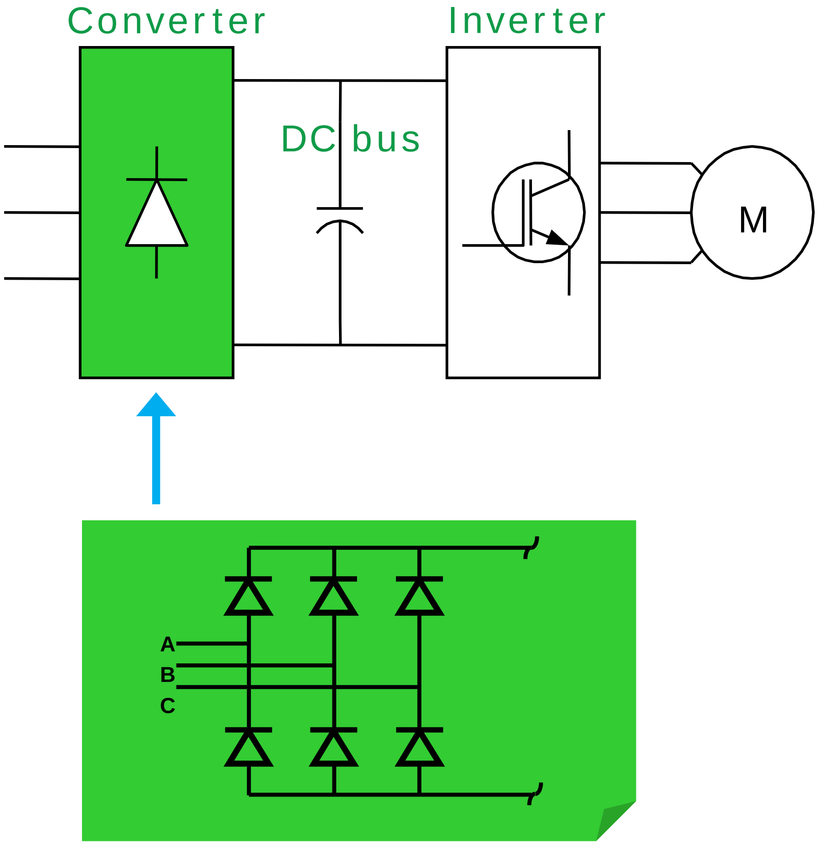
- Low energy efficiency
- High repair costs

Solution

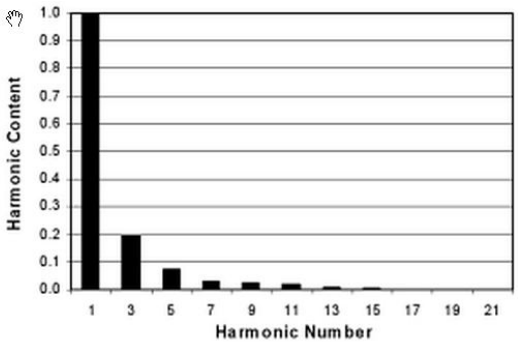
- Active Harmonic Filter
- Line inductances in front of "non-linear" loads
- Passive Harmonic Filter
- Distortion free devices

Waveform of a 6-Pulse VFD w/o Line Reactor – 90% Current Distortion





Harmonic Distortion - Voltage



Harmonic Voltage Distortion is the most pernicious Power Quality problem encountered in today's industrial, institutional and commercial facilities

Causes

- Usually, Current Distortion flowing through standard transformers
- Rarely, Distorted Voltage from Utility

Signs/Symptoms

- Sensitive equipment "crashing" intermittently: Computers, PLCs, VFDs, Medical equipment, Communication systems
- Motors overheating
- Capacitors failing prematurely
- High replacement rate for sensitive electronics

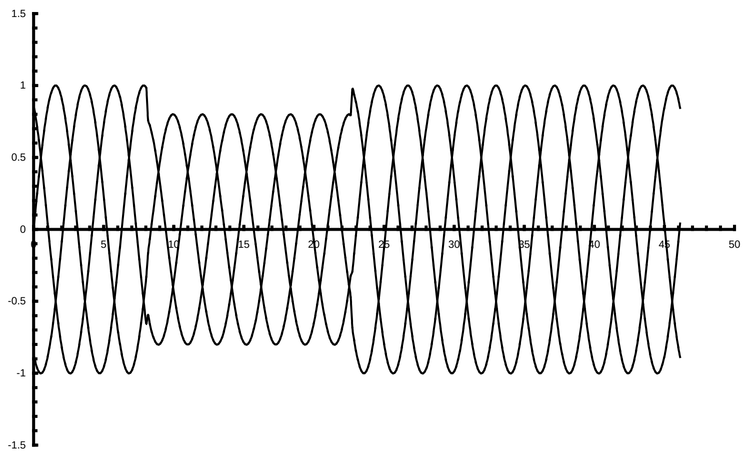
Business Impact

- Unreliable electrical system: Downtime
- Intermittently unavailable IT and financial transaction systems
- High repair costs
- Low energy efficiency

Solution

- Eliminate Current Distortion

Sags / Swells



Voltage sags (also referred to as "dips") are temporary reductions in voltage typically lasting from a half cycle to several seconds. If they are "mild" and prolonged they will be called "Undervoltage"

Voltage swells are temporary increases in voltage typically lasting from a half cycle to several seconds

Causes

- Sags result from high currents, typically due to faults or starting motors, interacting with system impedances on the Utility Grid
- Swells are commonly caused by the de-energizing of large loads or asymmetrical faults on the Utility Grid

Signs/Symptoms

- Sags: Sensitive electronic/electrical equipment shuts off
- Swells: Insulation breakdown in sensitive electronic equipment; High replacement rate

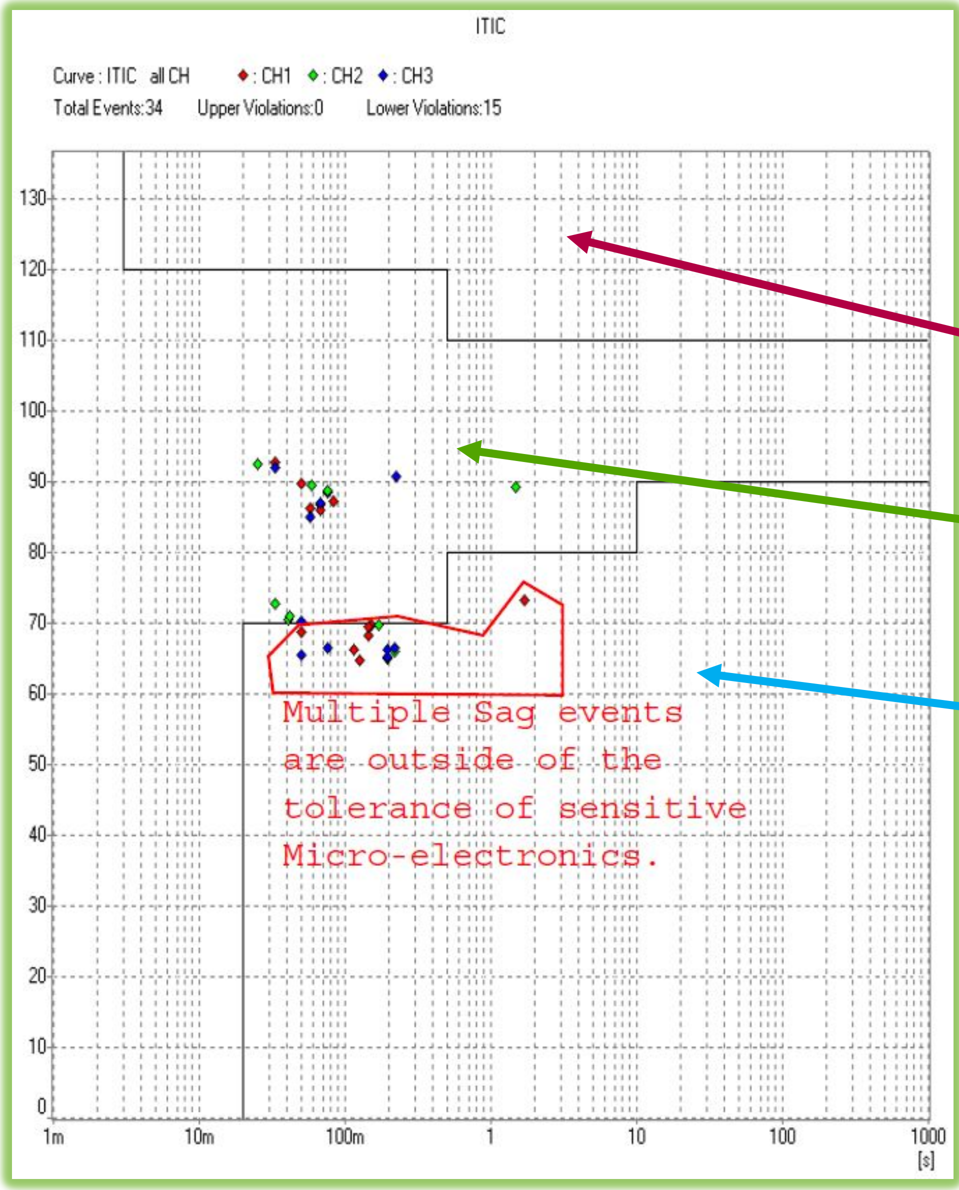
Business Impact

- Unreliable electrical system: Downtime
- Intermittently unavailable IT and financial transaction systems
- High repair costs
- Low energy efficiency

Solution

- Voltage Regulator or SagFighter applied in series with the load

Effect of Sags / Swells on sensitive equipment



- The Information Technology Industry Council (ITIC) curve shows the voltage tolerances which sensitive electronic equipment must withstand
- Voltages above the envelope may damage the equipment
- Voltages within the envelope must permit normal operation of the equipment
- Voltages below the envelope may cause the equipment to malfunction or shutdown

PROBLEM SOLVING METHODOLOGY

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Power Quality solving methodology

Existing facilities

- Power Quality Audits conducted by a REMOTE Power Quality Team utilizing Permanent meters are the ideal solution because the customer has Quick access to the highest level of Power Quality professionals with no travel costs

- If necessary, temporary Power Monitoring equipment will be installed in strategic locations to gather Power Quality and Energy consumption data

New construction

- Modeling tools are used instead of Power Quality measurements

- In both cases the methodology is the same:
  1. Identify the source of the problems
  2. Quantify the criticality of the problems and financial impact to the customer's business
  3. Provide Power Quality Report and recommend one or more solutions to the problems
  4. Solve the problem(s) with the appropriate solutions/products

Power Quality solving methodology

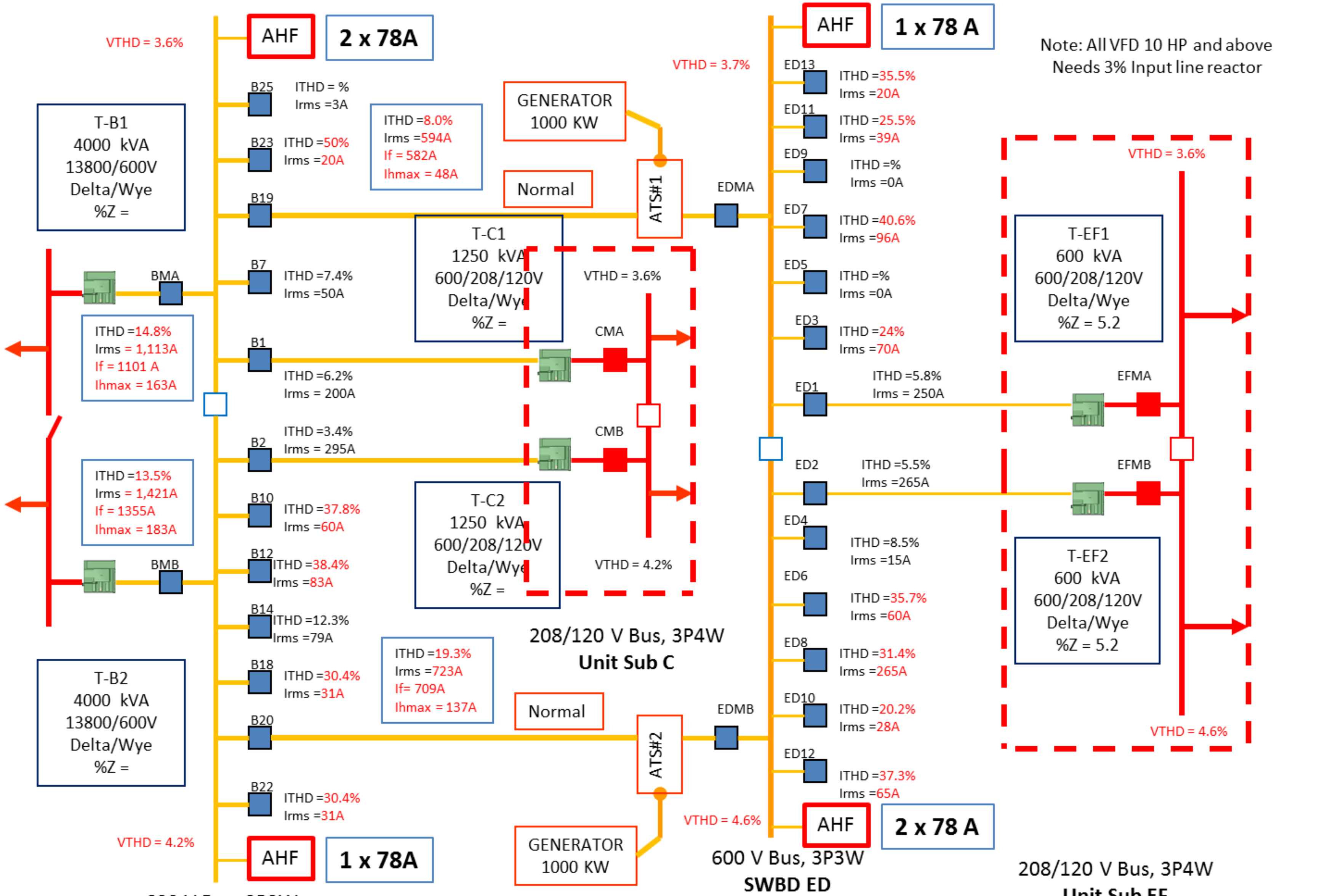

Fig. 2. Simplified Single Line Diagram

SOLUTIONS TO POWER QUALITY PROBLEMS

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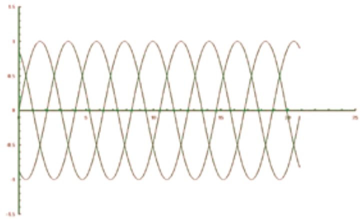
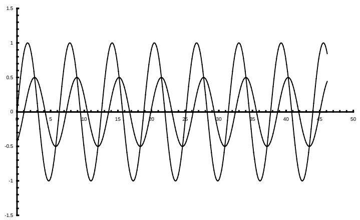
Power Factor Correction Capacitor Banks

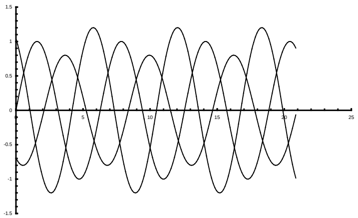


3-phase balanced

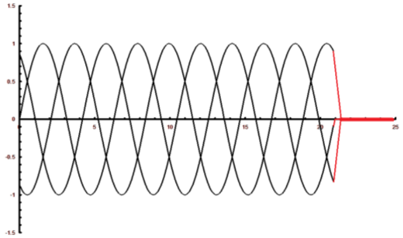


Power Factor

Harmonics



Phase unbalance



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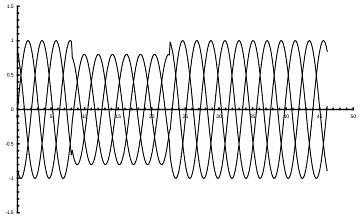
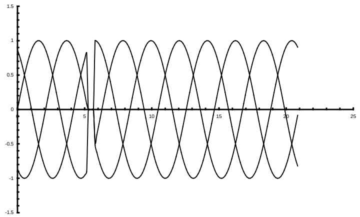


Sags/swells

Overvoltage



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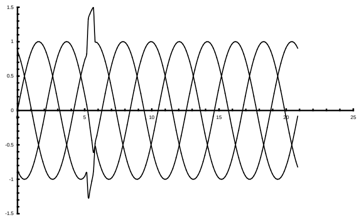

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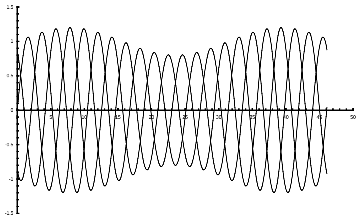

Flicker

Noise

Power Factor Correction Capacitor Banks

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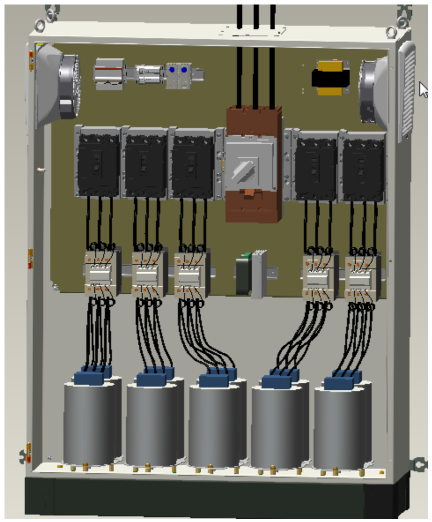
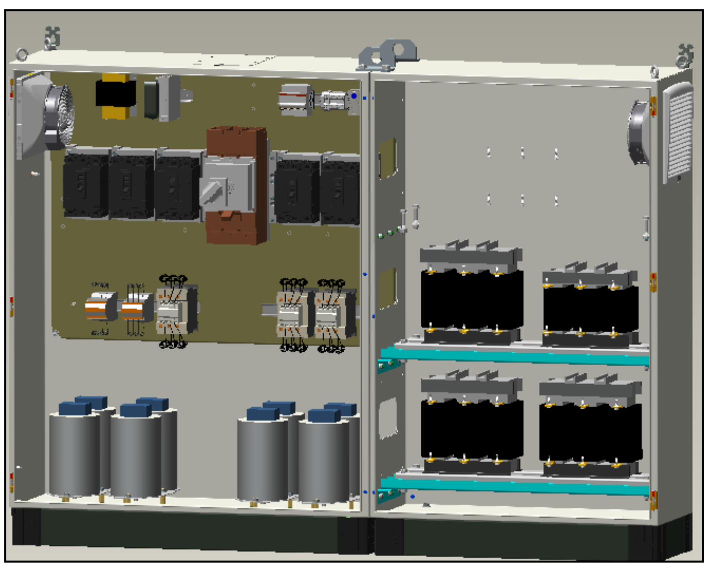
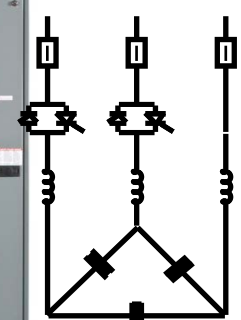
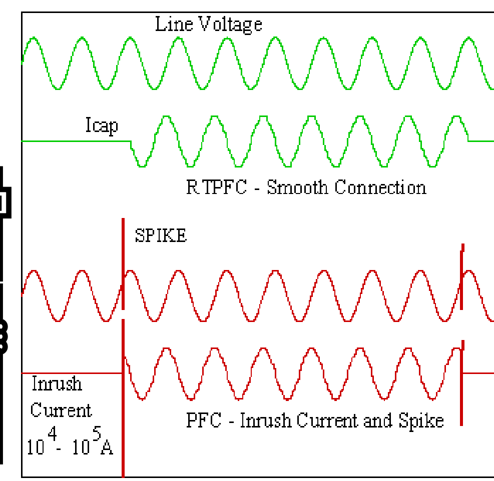


Commercial



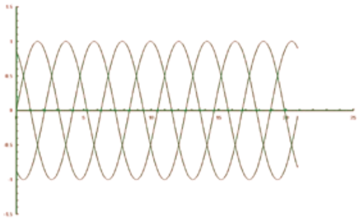
Industrial





Critical networks

AccuSine PQ Inverter



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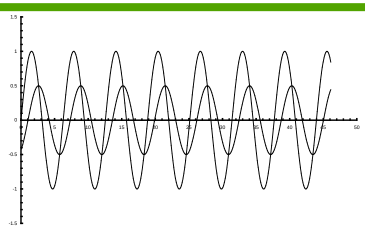
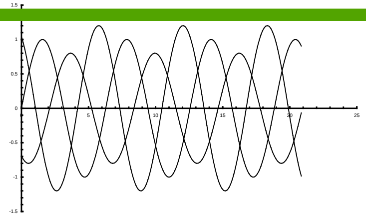
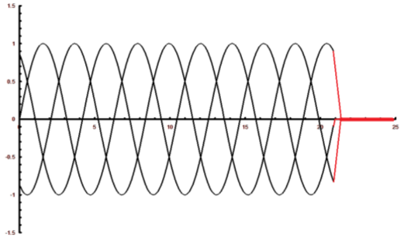


Power Factor

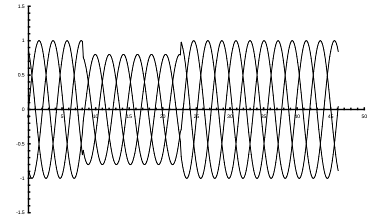
Harmonics



Phase unbalance

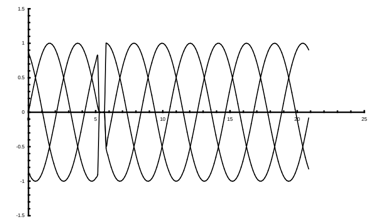


Blackout



Sags/swells

Overvoltage



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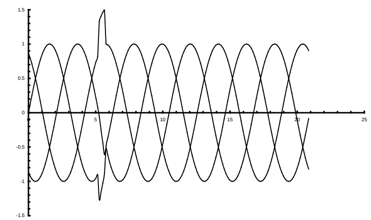

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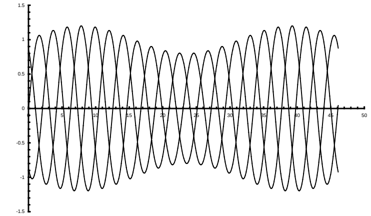
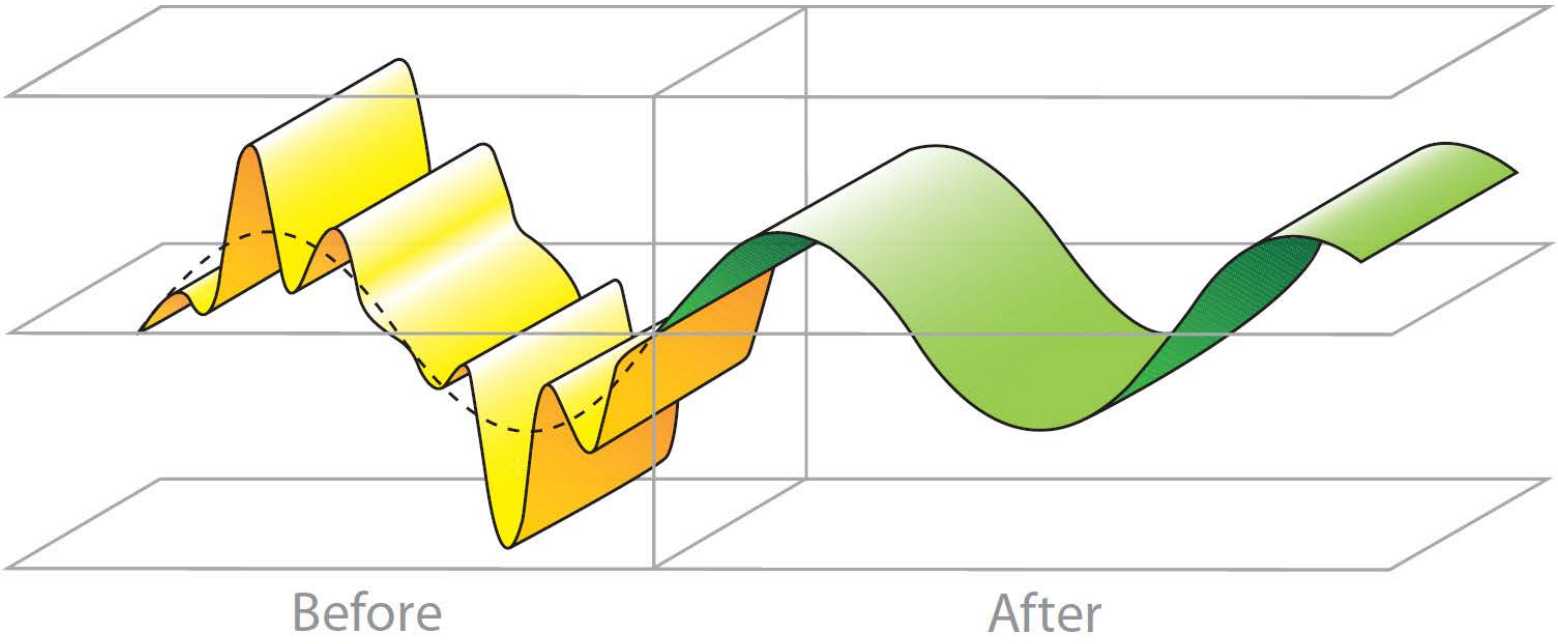


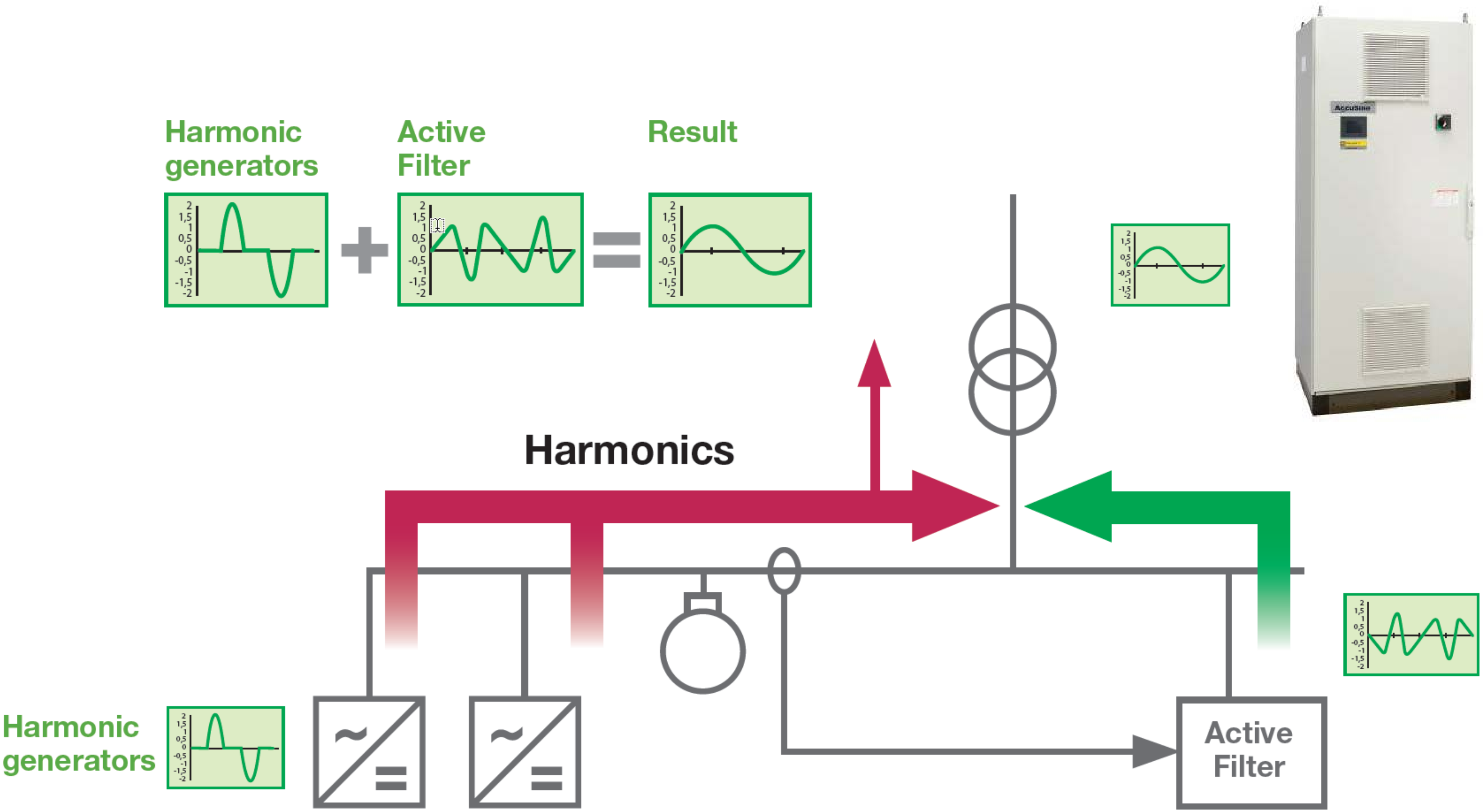
Flicker

Noise

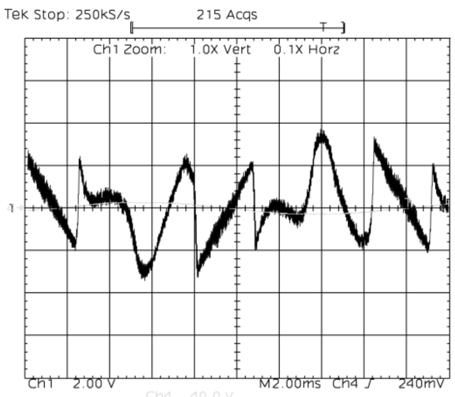
AccuSine Active Harmonic Filter

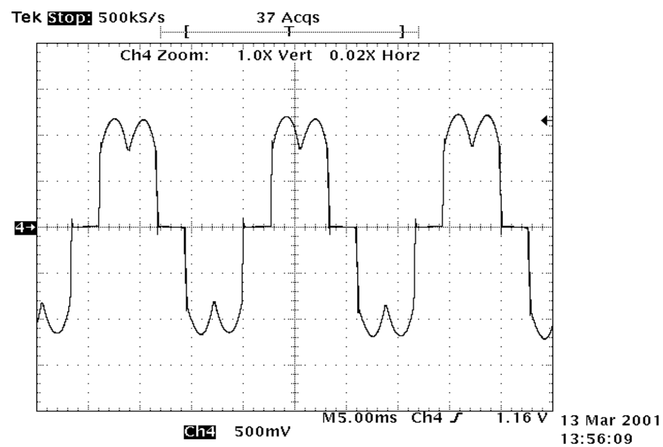


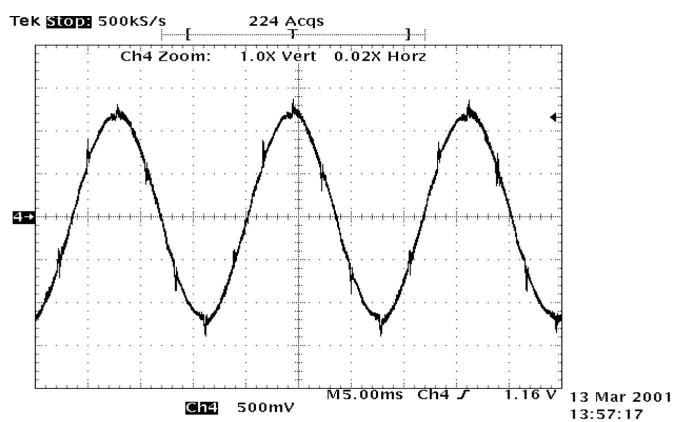
AccuSine Active Harmonic Filter



AccuSine Active Harmonic Filter Performance

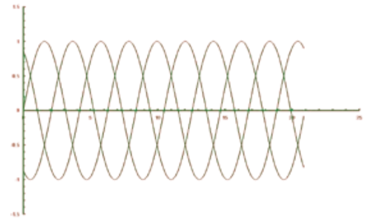




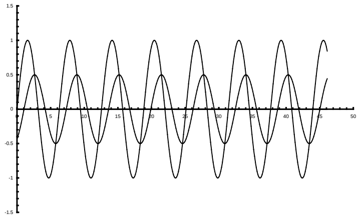


	AS off	AS on
Order	% I fund	% I fund
Fund	100.000%	100.000%
3	0.038%	0.478%
5	31.660%	0.674%
7	11.480%	0.679%
9	0.435%	0.297%
11	7.068%	0.710%
13	4.267%	0.521%
15	0.367%	0.052%
17	3.438%	0.464%
19	2.904%	0.639%
21	0.284%	0.263%
23	2.042%	0.409%
25	2.177%	0.489%
27	0.293%	0.170%
29	1.238%	0.397%
31	1.740%	0.243%
33	0.261%	0.325%
35	0.800%	0.279%
37	1.420%	0.815%
39	0.282%	0.240%
41	0.588%	0.120%
43	1.281%	0.337%
45	0.259%	0.347%
47	0.427%	0.769%
49	1.348%	0.590%
% THD(I)	35.28%	2.67%

Voltage Regulator and SagFighter

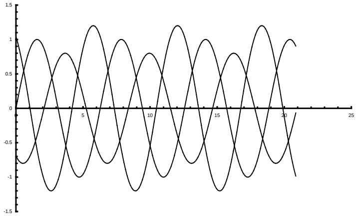


3-phase balanced

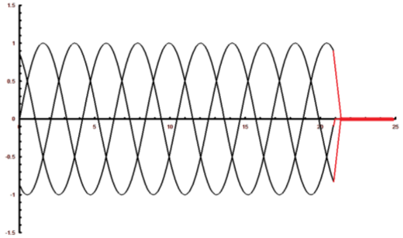


Power Factor

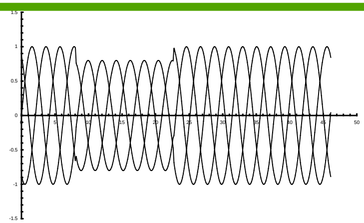
Harmonics



Phase unbalance

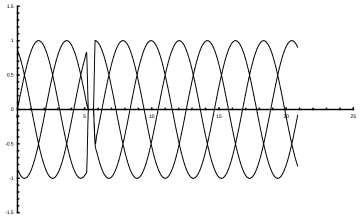


Blackout

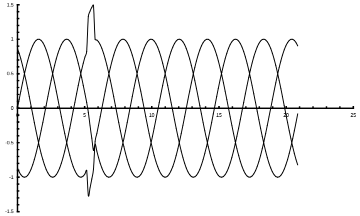


Sags/swells

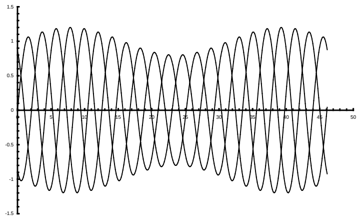
Overvoltage



notches



Transient (Spike)

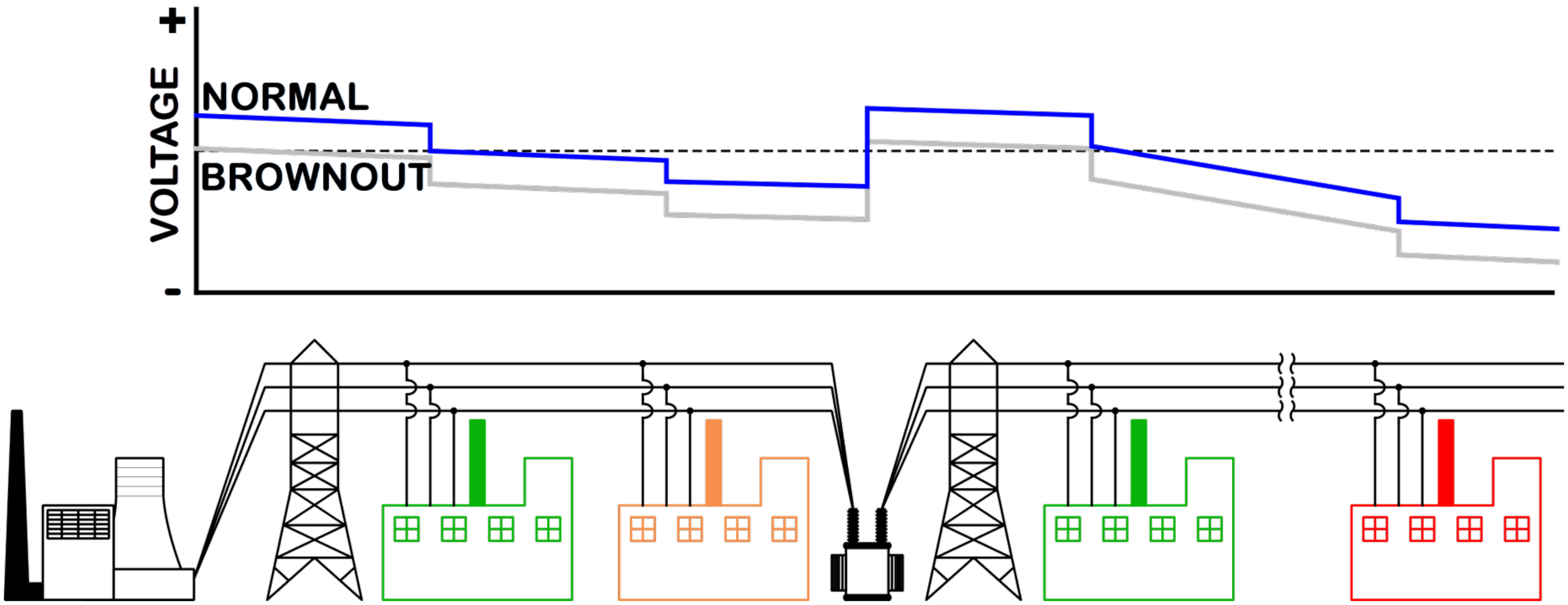


Flicker

Noise

Voltage Regulator

Schneider Electric



Brownout – intentional reduction in grid voltage

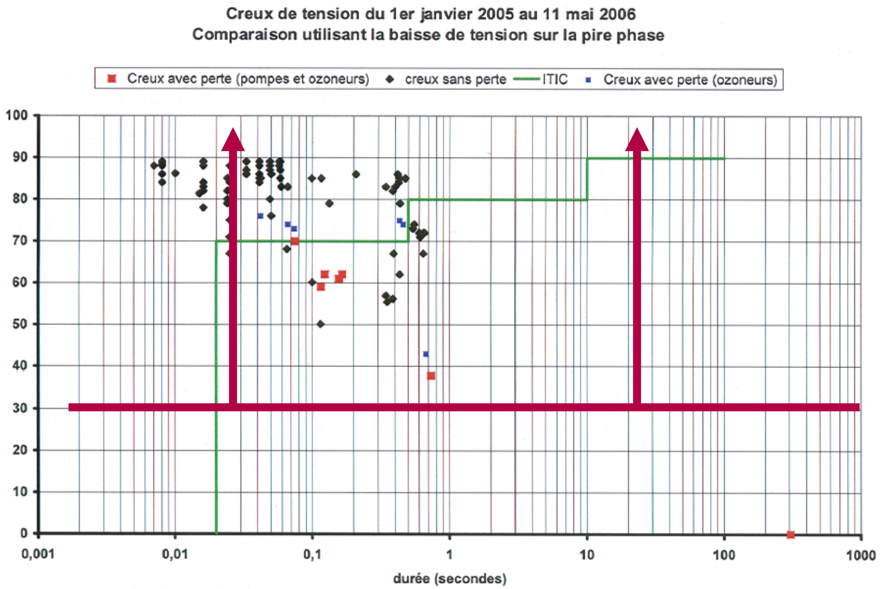
External: Line Drops & Brownouts

Sure-Volt ™ - Voltage regulator

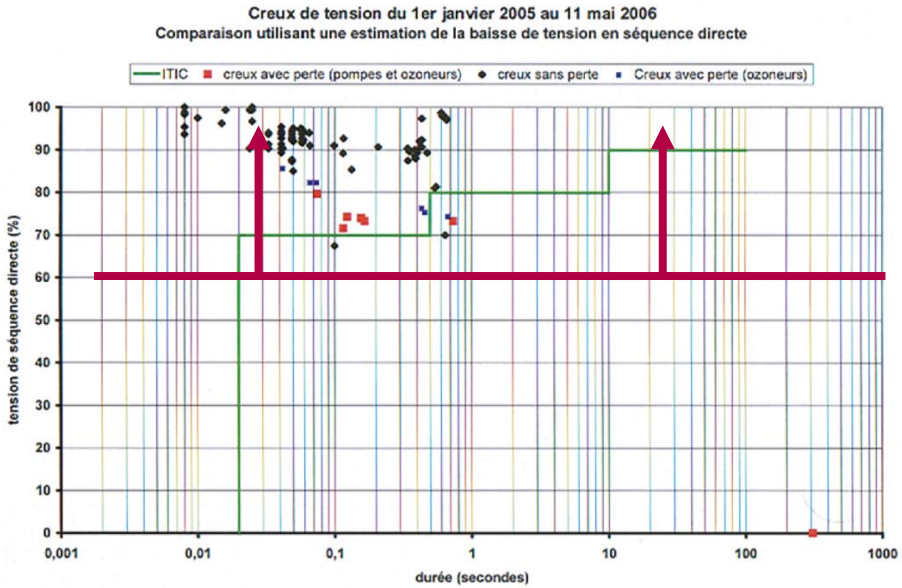
The standard Sure-Volt™:

- Microprocessor controlled tap-switching
- Input voltage range: **+10 to -25%**
- Output regulation: **±3%**
- Response time: 1 cycle typical
- Fan-free and maintenance-free
- Single or three phase
- 5 to 2,000 kVA
- Any input or output voltages up to 600v

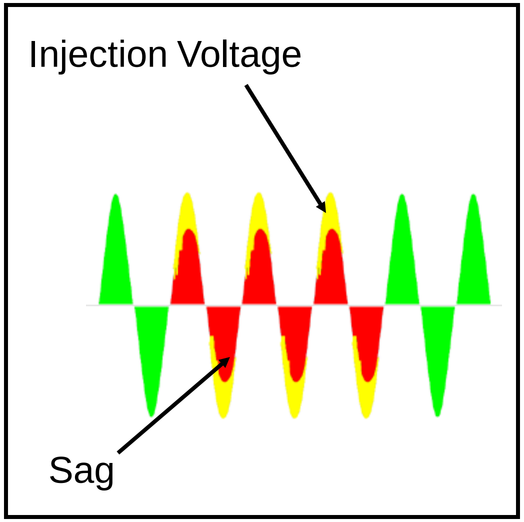
Single Phase Sags

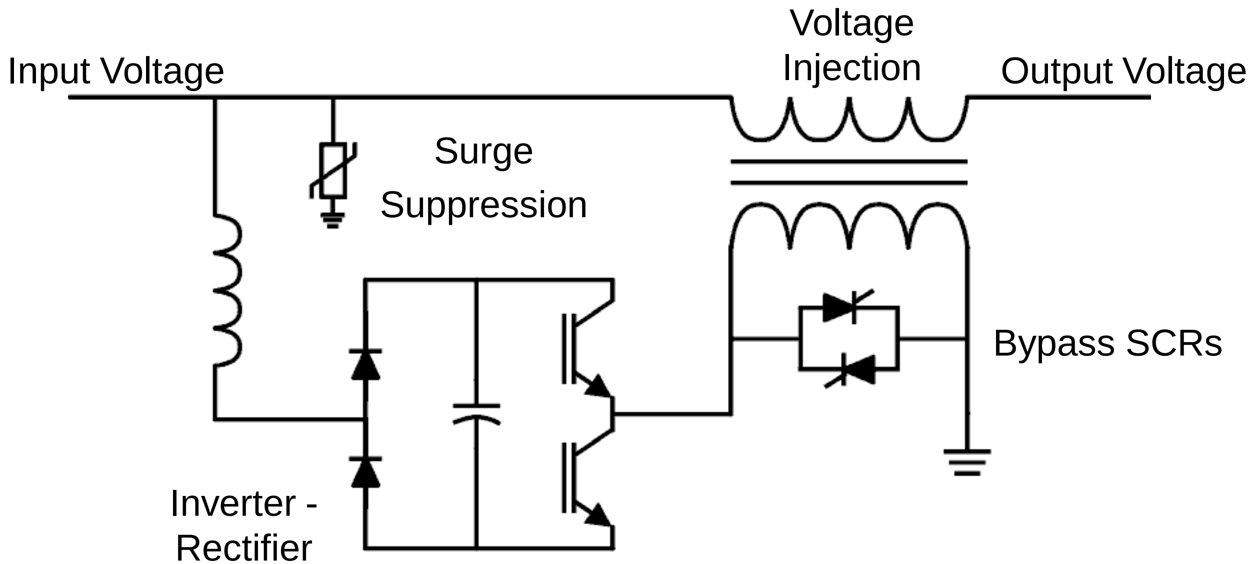


Three Phase Sags



Sag Fighter™ Operation





Draws extra current from the "good" legs to create an injection voltage

Back

Front

Front

ONE FINAL WORD….

Charlatan

Beware of those who claim their box can solve all your Power Quality problems

THANK YOU