MIRUS International Inc.

Harmonic and Energy Saving Solutions

Passive Harmonic Solution for VFD's - Introducing Lineator AUHF

Talayeh Ameri, Sales and Applications Support Engineer

MIRUS Is Harmonic Mitigation

MIRUS International Inc.

MIRUS International Inc. designs and develops world-class power quality improvement products for mission critical operations. Our solutions minimize disruption to power supply, improve reliability and adhere to the strictest regulatory requirements while saving energy and reducing operating costs.

Harmonics are a Massive Pain for Oil & Gas, Marine, HVAC, Water/Wastewater, Data Centers and Industrial and Commercial Facilities

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- Harmonic disturbances damage expensive equipment, cause failure, and add expense via maintenance, replacement, energy consumption, etc.
- A solution is needed to mitigate disruptions, high costs and associated risks.
- A proactive approach helps solve harmonic issues and prevent future problems.

Our Solution in Action

MIRUS International Inc.


Land and Offshore Drilling Rig

USA Coast Guard Vessels

Oil Rig & Production Platform Service Vessels


Royal Navy Aircraft Carrier

Our Solution in Action

MIRUS International Inc.

Heating Ventilation Air Conditioning (HVAC)

1300 HP Chiller at an Aerospace Mfg Facility

Non-linear Lighting Load on Film Sets

Water and Waste Systems

6- Pulse Rectifier and Harmonics

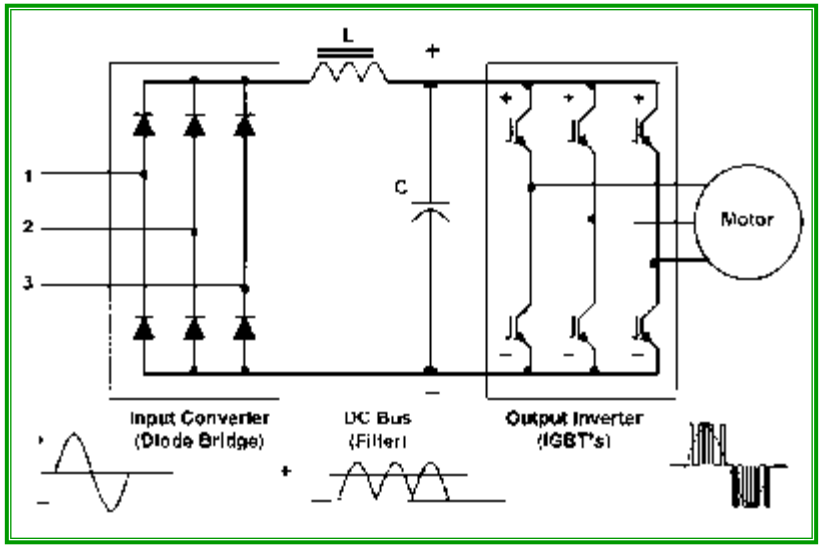
For simple diode bridge rectifiers:

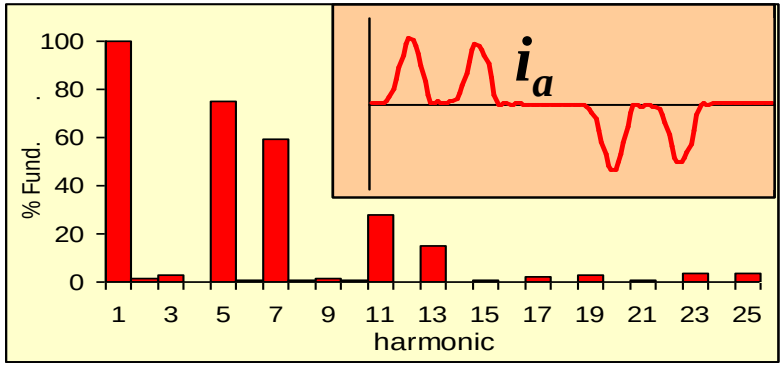
$$h = np \pm 1$$

$$I_h = \frac{I}{h}$$

h = harmonic number
p = # of pulses in rectification scheme
n = any integer (1, 2, 3, etc.)
I_h = magnitude of harmonic current
(addition of DC bus cap increases I_h)

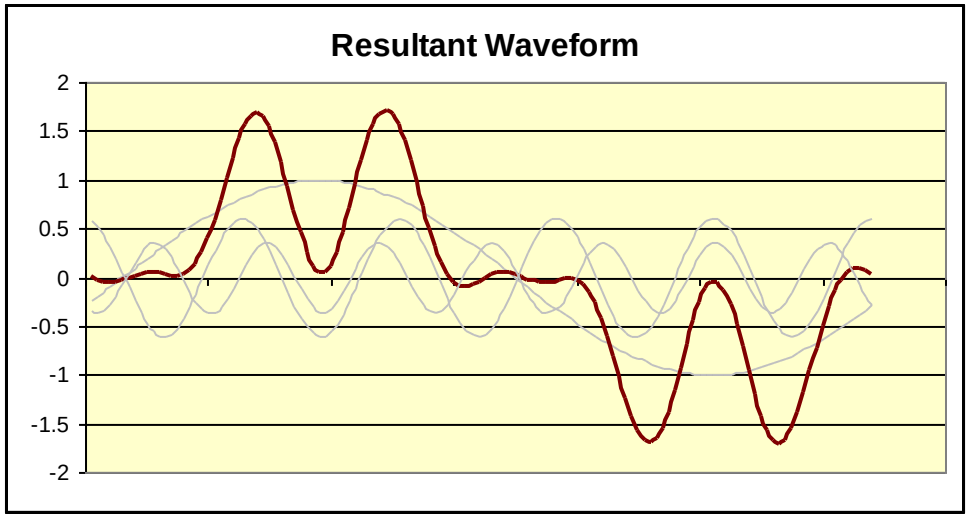
When, p = 6
h = -- 5,7,--,11,13,--,17,19...





Current Waveform and Spectrum

Harmonics – Components of a Distorted Waveform



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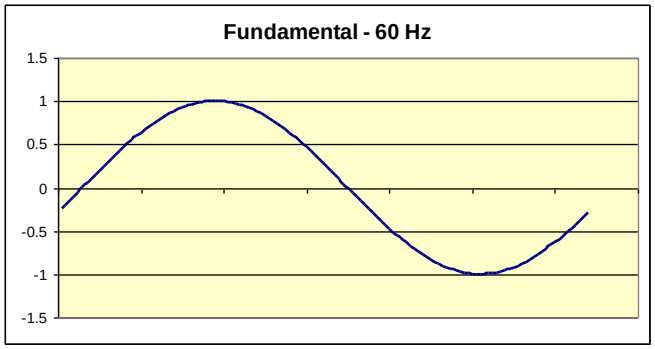

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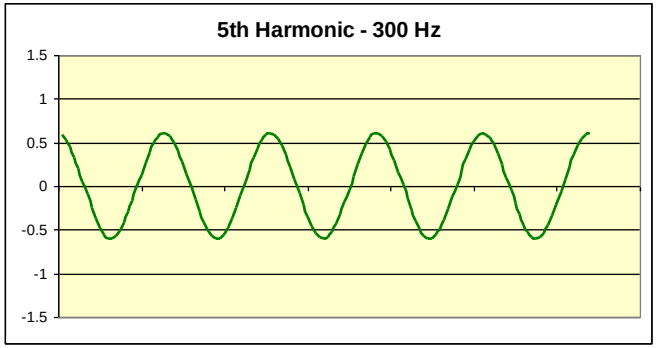

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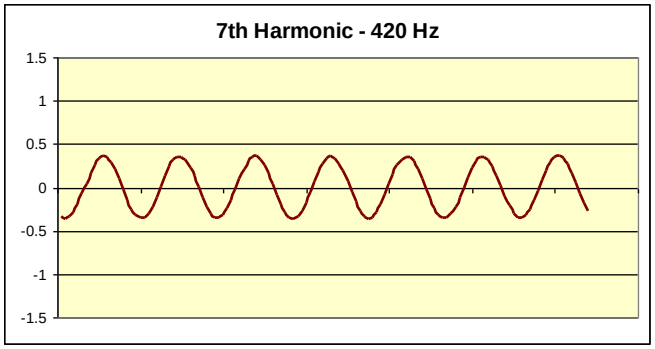
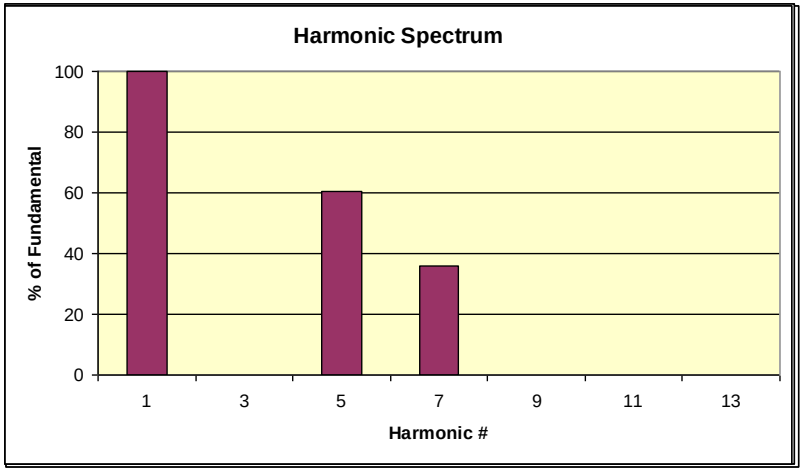
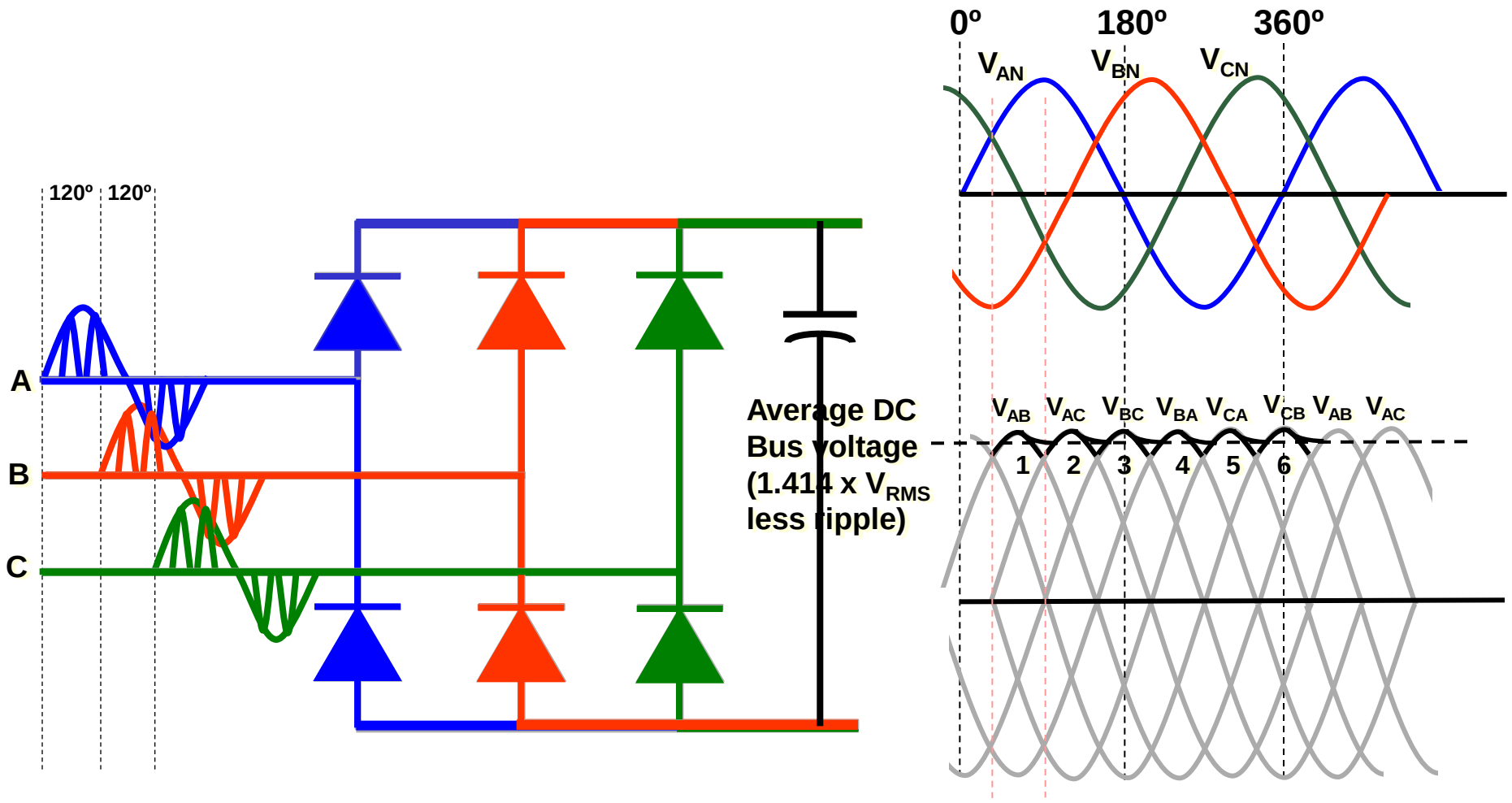




Fourier Series

$f(t) = A_o+A_1\sin(wt+\theta_1)+A_2\sin(2wt+\theta_2)+A_3\sin(3wt+\theta_3)$ ...

3-Phase Rectifier Operation: 6-Pulse



What Problems can VFD Harmonics Create?

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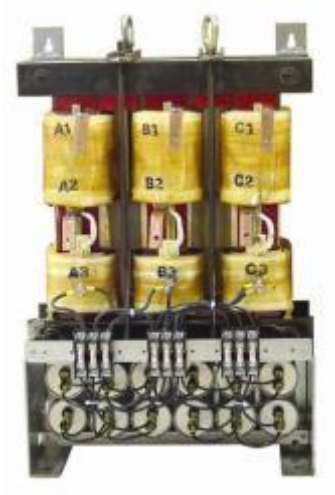
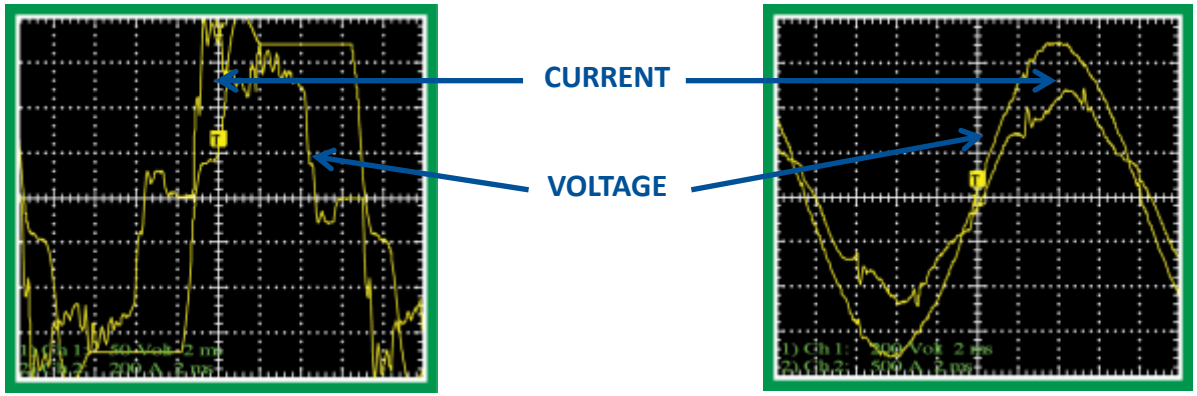
- Distortion of supply voltage causing premature failure or misoperation of connected equipment
- Over heating of distribution equipment such as cables, transformers and generators
- False operation of circuit breakers and other protection devices
- Over heating of motors and other connected equipment
- Low power factor resulting in electrical bill penalties and requiring transformer kVA upsizing
- Failure of PF correction capacitors
- Metering errors (not a problem with digital meters)
- Voltage regulation problems on generators
- Power system resonance which can amplify the problem

LINEATOR™ Advanced Universal Harmonic Filter (AUHF)

MIRUS International Inc.





Input Without Filter Installed

Input With Filter Installed

- Input harmonic filter for VSDs
- 18-pulse performance with 6-pulse VSD
- Meets IEEE std 519 harmonic limits
- Revolutionary reactor design
- Near unity power factor
- Generator compatibility
- Extremely high efficiency
- Sizes up to 3500HP (2600kW)

Lineator Internal Connection Diagram

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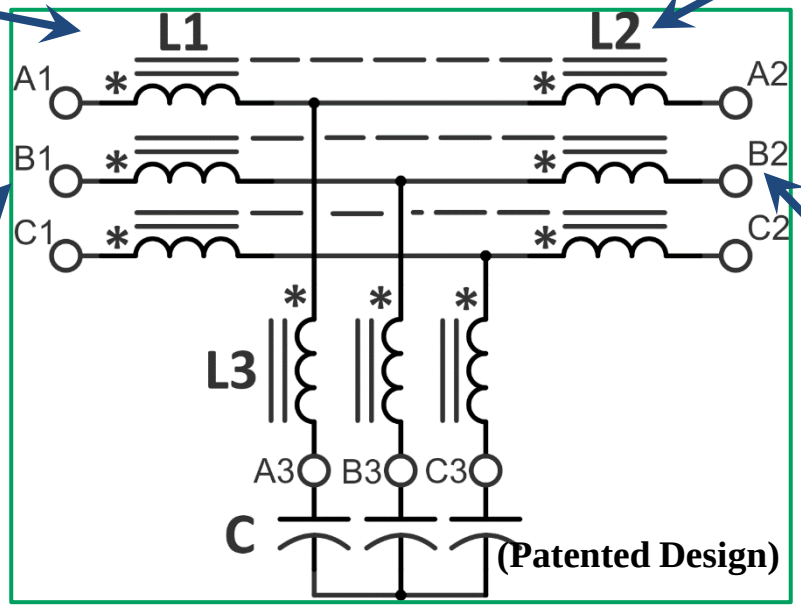
Multiple windings on a common core

High impedance L1 winding

Compensating winding L2 lowers through impedance, reducing voltage drop



Input tuned below 5th to prevent importation of upstream harmonics

Output tuned near 7th to remove load side harmonics

Unique reactor design allows for smaller cap bank to reduce voltage boost and reactive power at no load

Lineator Performance on 150 HP (110 kW) PWM VFD

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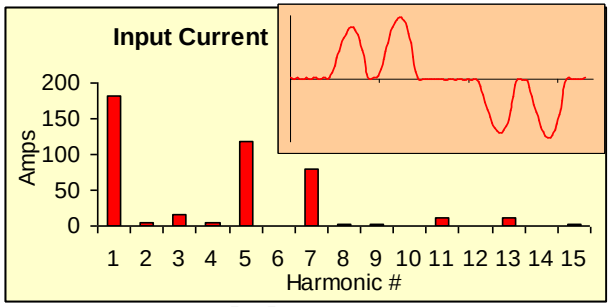
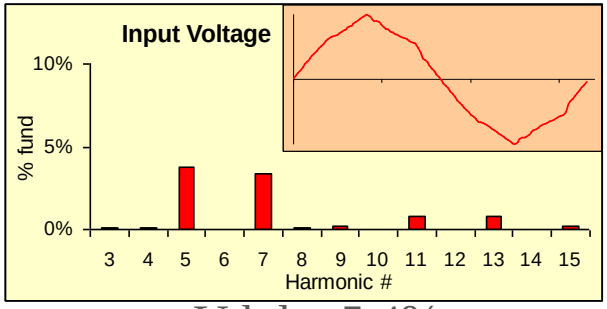
Without Harmonic Treatment

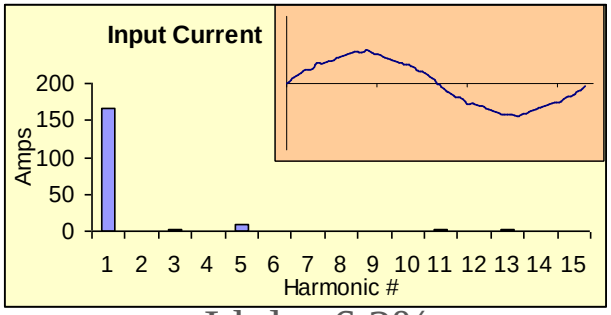


Ithd = 79%

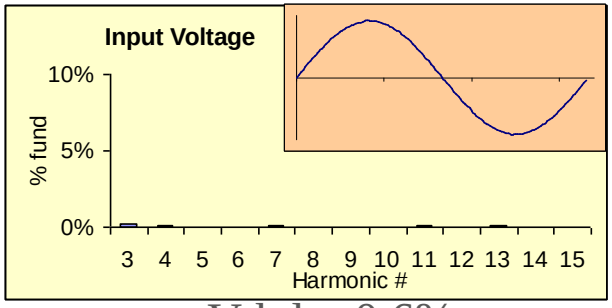


Vthd = 5.4%

With LINEATOR



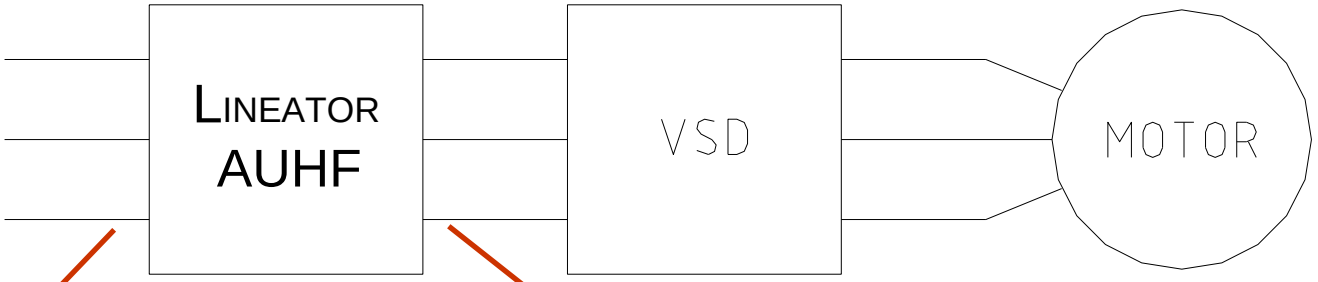
Ithd = 6.2%



Vthd = 0.6%

	Current Harmonics (Amps)																	
	RMS		5th		7th		11th		13th		Ithd		Itdd		K-factor		PF	
Load	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With	w/o	With
Full	233	168	118	9.0	80	0.6	12	2.2	12	1.5	79%	6.2%	79%	6.2%	15	1.5	- .75	1.00
75%	187	130	96	7.7	70	0.6	15	1.5	7	1.4	86%	7.0%	65%	5.3%	17	1.6	- .73	+ .99
50%	134	89	69	6.9	54	0.3	17	1.2	5	1.0	95%	9.0%	48%	4.5%	20	2.0	- .69	+ .95
25%	67	46	33	4.2	29	0.2	14	0.8	9	1.0	120%	11%	30%	2.8%	29	2.5	- .58	+ .83

Lineator Provides Protection Against Line-Side Transients



INPUT

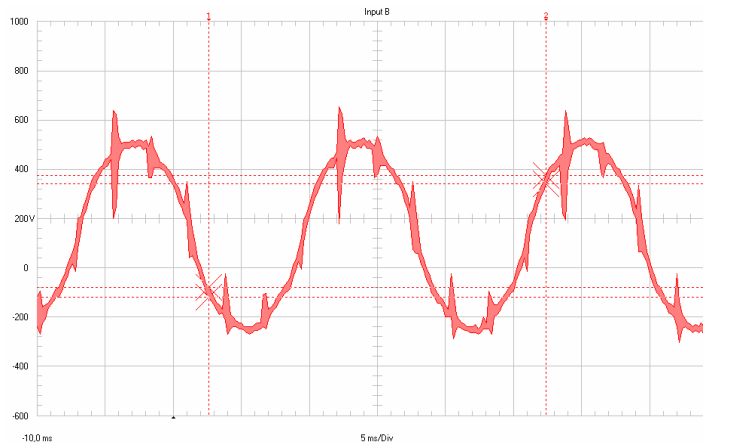


Figure 2: Voltage waveform at input to harmonic filter

OUTPUT

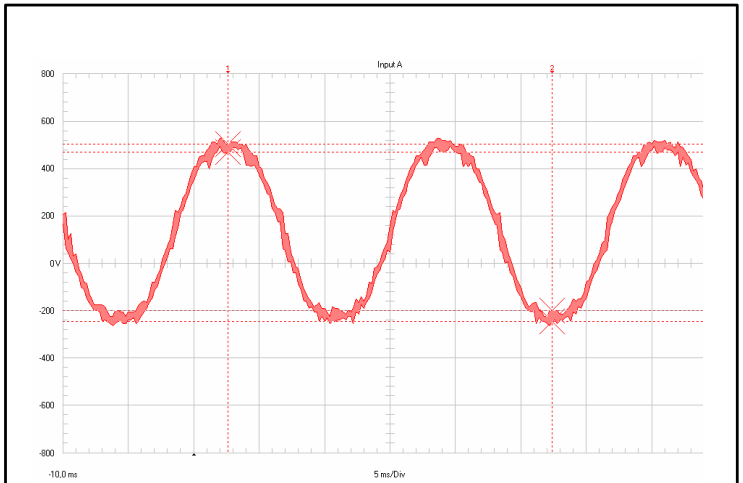


Figure 3: Voltage waveform at output of harmonic filter supplying AC Drive

Voltage Notching Caused by DC Drives on Off-shore Oil Platform

Notches Dramatically reduced on Output of Lineator AUHF

SOLV Computer Simulation Software

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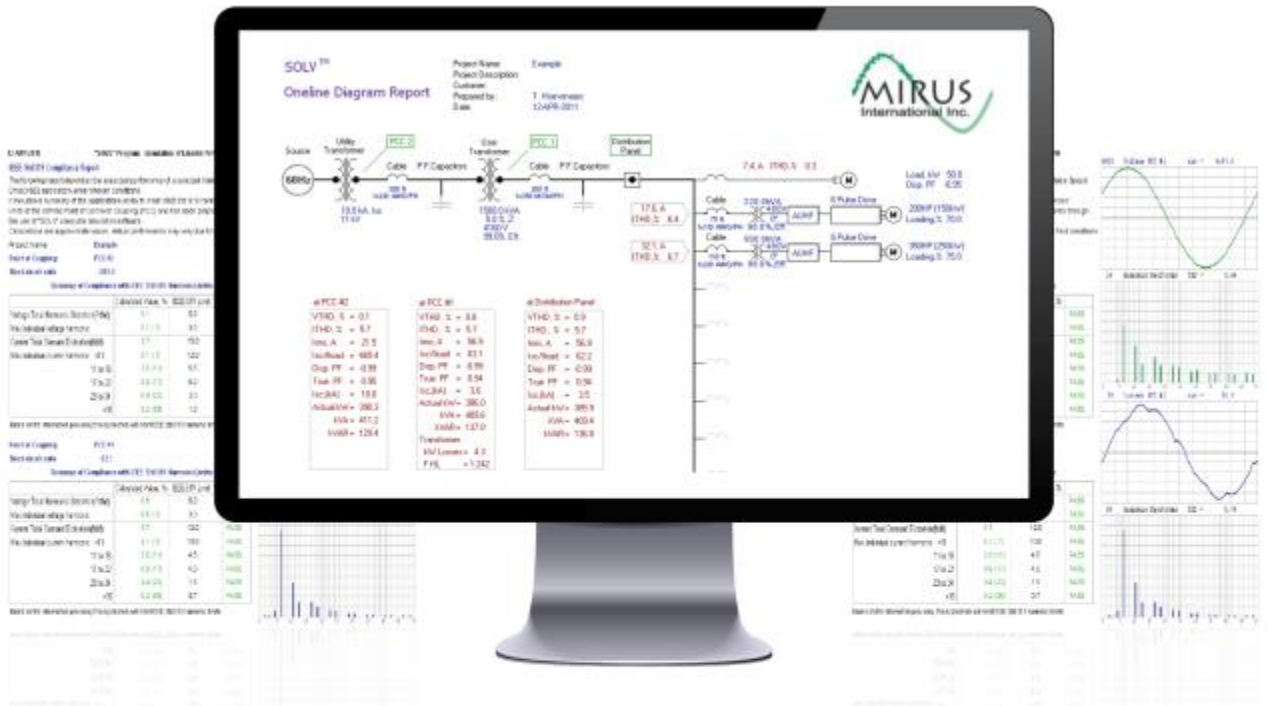


- Calculates current and voltage distortion levels by simulating Variable Speed Drive (VSD) applications with and without harmonic mitigation (Lineator AUHF)
- Comparison to IEEE Std519 harmonic limits
- Performs energy savings analysis
- Allows for voltage imbalance and background voltage distortion

Case Study - SkyVenture Free-fall Simulator

Wind tunnel powered by large blowers provides novice and expert thrill-seekers the experience of free-fall

Challenge:

- 4 x 350HP VFD's used to achieve required wind speeds
- Local Utility required evidence that IEEE Std 519 harmonic limits would be met
- Energy savings also considered to be very important

Solution:

- Computer simulation was used to demonstrate:
  - Line reactors alone would not meet limits
  - Passive harmonic filter would meet limits
  - Significant energy savings when compared to 18-Pulse

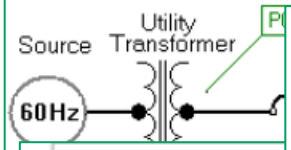
SkyVenture Free-fall Simulator – Montreal
Computer Simulation with AC Line Reactor

MIRUS International Inc.

SOLV™

Oneline Diagram Report

Project Name: Sky Venture Montreal
Project Description: 2 x 350HP Blowers on eac
Customer: Sky Venture
Prepared by :
Date: 10-MARCH-2011



VTHD, % 1.
ITHD, % = 19
Irms, A = 3
Isc/Iload = 10
Disp. PF = -0
True PF = 0.
Isc,(kA) = 4
Actual kW 14
kVA = 15
kVAR 58

F HL = 2.185

10-MARCH-2011 "SOLV" Program - Simulation of Lineator/VFD

IEEE Std 519 Compliance Report

The following report describes the expected perfomance of a selected Variable Speed Drive(VSD) application under chosen conditions.
It includes a summary of the applications ability to meet IEEE Std 519 harmonic limits at the defined Point of Common Coupling (PCC) and has been prepared through the use of "SOLV" computer simulation software.

Point of Coupling: PCC #1

Short-circuit ratio 16.6

Summary of Compliance with IEEE Std 519 Harmonic Limits:

	Calculated Value, %	IEEE-519 Limit, %	
Voltage Total Harmonic Distortion(Vthd)	7.2	5.0	FAIL
Max.Individual voltage harmonic	5.6 { 5}	3.0	FAIL
Current Total Demand Distortion(Itdd)	19.5	5.0	FAIL
Max.Individual current harmonic <11	18.2 { 5}	4.0	FAIL
11 to 16	2.9 {11}	2.0	FAIL
17 to 22	1.0 {17}	1.5	PASS
23 to 34	0.7 {23}	0.6	FAIL
>35	0.3 {35}	0.3	PASS

Based on the information provided, this application will NOT meet IEEE Std 519 harmonic limits

Current Total Demand Distortion(Itdd)	19.5	5.0	FAIL
Max.Individual current harmonic <11	18.2 { 5}	4.0	FAIL
11 to 16	2.9 {11}	2.0	FAIL
17 to 22	1.0 {17}	1.5	PASS
23 to 34	0.7 {23}	0.6	FAIL
>35	0.3 {35}	0.3	PASS

Based on the information provided, this application will NOT meet IEEE Std 519 harmonic limits

SkyVenture Free-fall Simulator – Montreal
Computer Simulation with Lineator AUHF

MIRUS International Inc.

SOLV™

Oneline Diagram Report

Project Name: Sky Venture Montreal
Project Description: 2 x 350HP Blowers on each c
Customer: Sky Venture
Prepared by :
Date: 10-MARCH-2011

Source Utility Transformer PC

at PCC #2

VTHD, %= 0.4
ITHD, %= 4.1
Irms, A = 38.(
Isc/Iload= 110.
Disp. PF= -0.9
True PF= 0.9
Isc,(kA) = 4.2
Actual kW=1462
kVA= 1513
kVAR= 388.

F HL =1.138

10-MARCH-2011 "SOLV" Program - Simulation of Lineator/VFD

IEEE Std 519 Compliance Report

The following report describes the expected perfomance of a selected Variable Speed Drive(VSD) application under chosen conditions.
It includes a summary of the applications ability to meet IEEE Std 519 harmonic limits at the defined Point of Common Coupling (PCC) and has been prepared through the use of "SOLV" computer simulation software.

Point of Coupling: PCC #1

Short-circuit ratio 16.9

Summary of Compliance with IEEE Std 519 Harmonic Limits:

	Calculated Value, %	IEEE-519 Limit, %	
Voltage Total Harmonic Distortion(Vthd)	2.4	5.0	PASS
Max.Individual voltage harmonic	1.5 {7}	3.0	PASS
Current Total Demand Distortion(Itdd)	4.1	5.0	PASS
Max.Individual current harmonic <11	3.5 {7}	4.0	PASS
11 to 16	1.7 {11}	2.0	PASS
17 to 22	0.7 {17}	1.5	PASS
23 to 34	0.3 {25}	0.6	PASS
>35	0.1 {35}	0.3	PASS

Based on the information provided, this application will meet IEEE Std 519 harmonic limits

Current Total Demand Distortion(Itdd)	4.1	5.0	PASS
Max.Individual current harmonic <11	3.5 {7}	4.0	PASS
11 to 16	1.7 {11}	2.0	PASS
17 to 22	0.7 {17}	1.5	PASS
23 to 34	0.3 {25}	0.6	PASS
>35	0.1 {35}	0.3	PASS

Based on the information provided, this application will meet IEEE Std 519 harmonic limits

SkyVenture Free-fall Simulator - Montreal

Energy Savings Analysis: 18-Pulse VFD vs Passive Harmonic Filter

- Operating Conditions:
  - 10 hrs/day, 364 days/yr
  - 80% load
  - $0.06 / kWhr
- Estimated energy savings at Utility Supply:
  - 47,334 kWhr/yr
  - $2,840 /yr

MIRUS International Inc.

SOLV Program - Simulation of Lineator/VFD
Comparison & Energy Analysis Report

Date *10-MARCH-2011*
Project Name: Sky Venture Montreal
Project Description: 2 x 350HP Blowers on each of 2 sides
Customer: Sky Venture
Prepared by:

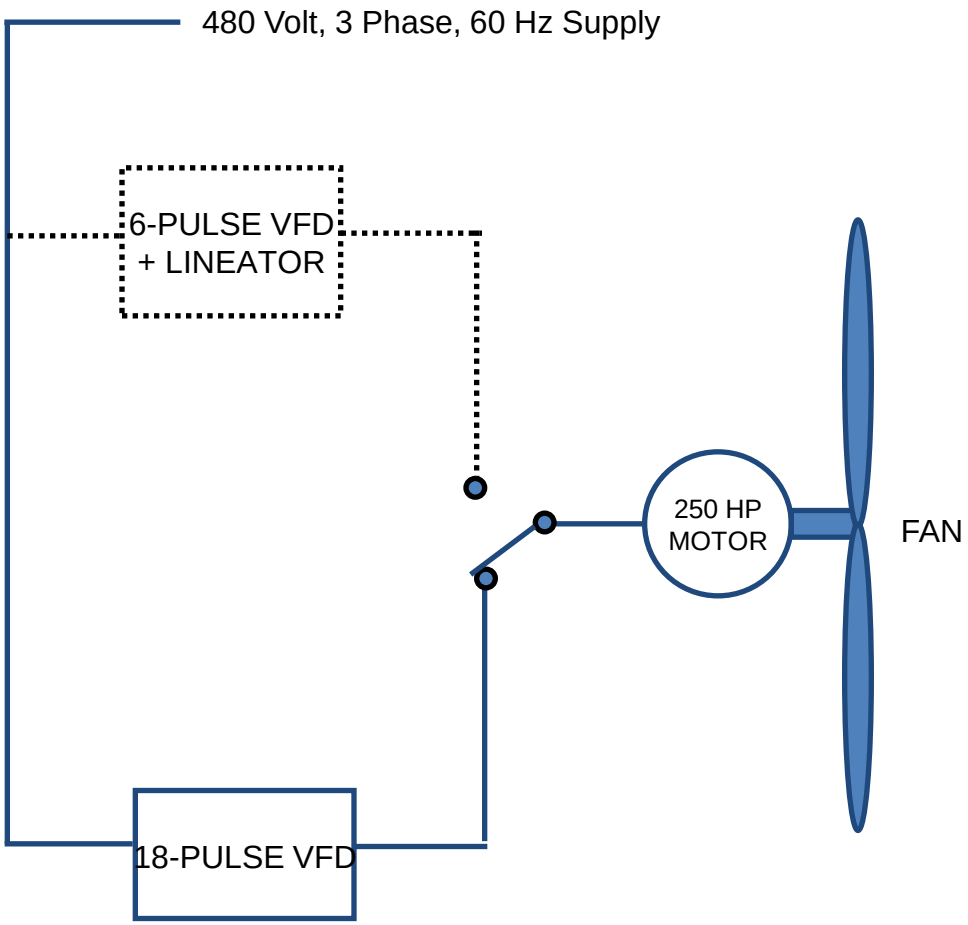
	Scenario A	Scenario B	Difference
Operating Info	PHF	18-P	
Currency	CAD	CAD	
Runtime (hrs/yr)	3640	3640	
Electricity Consumption Rate ($/kWhr)	0.060	0.060	
Electricity Demand ($/kW/month)	0.000	0.000	
Source	System	System	
System Frequency (Hz)	60	60	
Utility	Transformer	Transformer	
Size (kVA)	5000.0	5000.0	
Impedance (Z%)	3.0	3.0	
Fault Level (MVA)	----	----	
Short-Circuit Current (kA)	----	----	
Secondary Voltage (V)	23000.	23000.	
PCC #2			
Harmonic Voltage Distortion (%)	0.3	0.3	-0.0
Harmonic Current Distortion (%)	5.0	6.3	1.3
Total Current (Arms)	31.2	32.1	0.8
Displacement PF	-0.980	-0.975	0.005
True PF	0.974	0.974	-0.000
kVA	1245.6	1278.0	32.5
kVAR	184.3	289.3	105.0
Active kW	1231.9	1244.9	13.0
Energy Consumption (kWhr/yr)	4483960	4531294	47334
Energy Cost ($/yr)	269037	271877	2840
User Transformer			
Size (kVA)	1500.0	1500.0	
Impedance (Z%)	5.00	5.00	
Fault Level (MVA)	----	----	
Short-Circuit Current (kA)	----	----	
Secondary Voltage (V)	600.	600.	
kW Losses	13.6	13.7	0.1
Harmonic Loss Factor (FHL)	1.164	1.139	-0.025

SkyVenture Free-fall Simulator - Orlando

MIRUS International Inc.

Energy Savings Analysis: 18-Pulse VFD vs Lineator AUHF

Drive (Hz)	Fan (RPM)	18-pulse (kW)
55.92	818	152.47
60	889	190.03



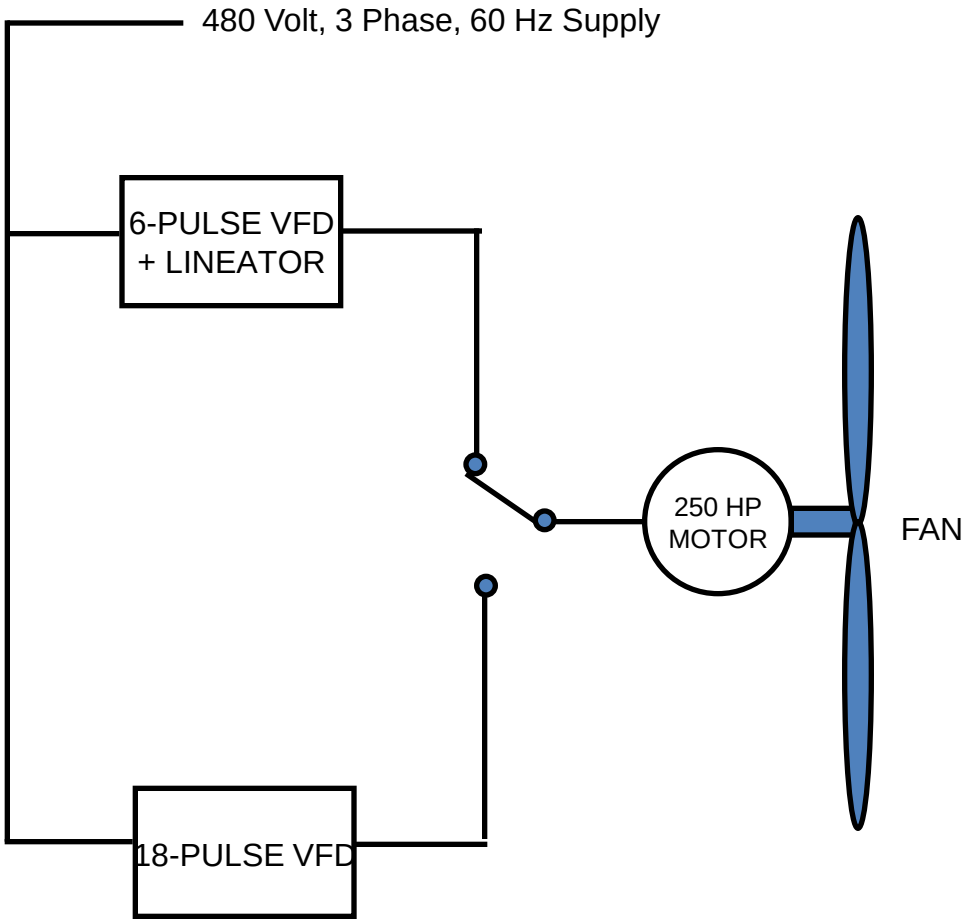
SkyVenture Free-fall Simulator - Orlando

MIRUS International Inc.

Energy Savings Analysis: 18-Pulse VFD vs Passive Harmonic Filter

KW SAVED WITH 6-PULSE VFD + LINEATOR
at 60 HZ : 6.89kW
at 55 HZ: 9.2kW

Drive (Hz)	Fan (RPM)	18-pulse (kW)	6-pulse VFD + Lineator (kW)
55.92	818	152.47	143.27
60	889	190.03	183.14



6-PULSE DRIVE + LINEATOR saved 3.5% to 6% of energy needed to run fan

Case Study: Savings through Harmonic Mitigation

MIRUS International Inc.

American Pipeline company reduced fuel, emissions and generator size by applying harmonic mitigation on a 200HP VFD pump application

Challenge:

- Failures and operational problems required that the supply generator be increased from 176kW to 500kW
- Fuel consumption and emissions increased due to harmonics and inefficient generator operation
- Voltage distortion high even on 500kW generator

	No Harmonic Mitigation	With 3% AC Reactor	With AUHF
VTHD	7.6%	5.4%	1.7%
ITHD	44.7%	32.0%	6.6%
Current (Amp)	198.8	191.5	180.3
Real Power (kW)	147.2	146.9	148.3

Computer Simulation of 500 kW Generator supplying 200HP Pump with VFD and Various Harmonic Treatments

Case Study: Savings through Harmonic Mitigation

MIRUS International Inc.

American Pipeline company reduced fuel, emissions and generator size by applying harmonic mitigation on a 200HP VFD pump application

Solution:

- Lineator (AUHF) Harmonic Filter installed
- VTHD reduced to < 3% ITHD reduced to < 6%
- kW, fuel consumption and emissions reduced
- Allowed for significant downsizing of generator
- Eliminated VFD failures

	500 kW (with AC Reactor)	500 kW (with AUHF)	300 kW (with AUHF)
Load (kW)	137.5	111.5	117.6
Load %	27.4	22.2	39.2
Fuel Consumption at % Load (gal/hr)	11.8	10.1	7.3
Fuel Consumption at 24 hrs/day (gal/mo)	8,496	7,272	5,256
Fuel Cost (USD/mo)	$32,285	$27,634	$19,973
Fuel Savings (USD/mo)	N/A	$4,651	$12,312
% Savings	N/A	14.4%	38.1%
Emissions ($kgCO_2$/hr)	120	103	74
Monthly Emissions ($kgCO_2$/mo)	86,400	74,160	53,280
Monthly Emissions Reduction ($kgCO_2$/mo)	N/A	12,240	33,120

China Operations

- Wholly Foreign Owned Enterprise (WFOE) located in Suzhou
- Acquired in 2014
- Modern 4,700 m^2 (50,000 sq ft) facility
- Production capacity over 1000 units/mo in small/medium sizes
- Certified ISO 9000 Quality System

China Operations

MIRUS International Inc.

Thank you.

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