SIEMENS

Ingenuity for life

A New Paradigm Opens

Replacing Low Voltage, Low Power Drives with Medium Voltage Solutions

Today's Speaker

Karl Heideck
Principal Business Developer
Siemens Industry

- 27 years of experience in industrial and drive systems
- Project Management, Business Development, Product & Engineering Management, Business and Sales Management experience
- Author and Speaker: IEEE, PCIC

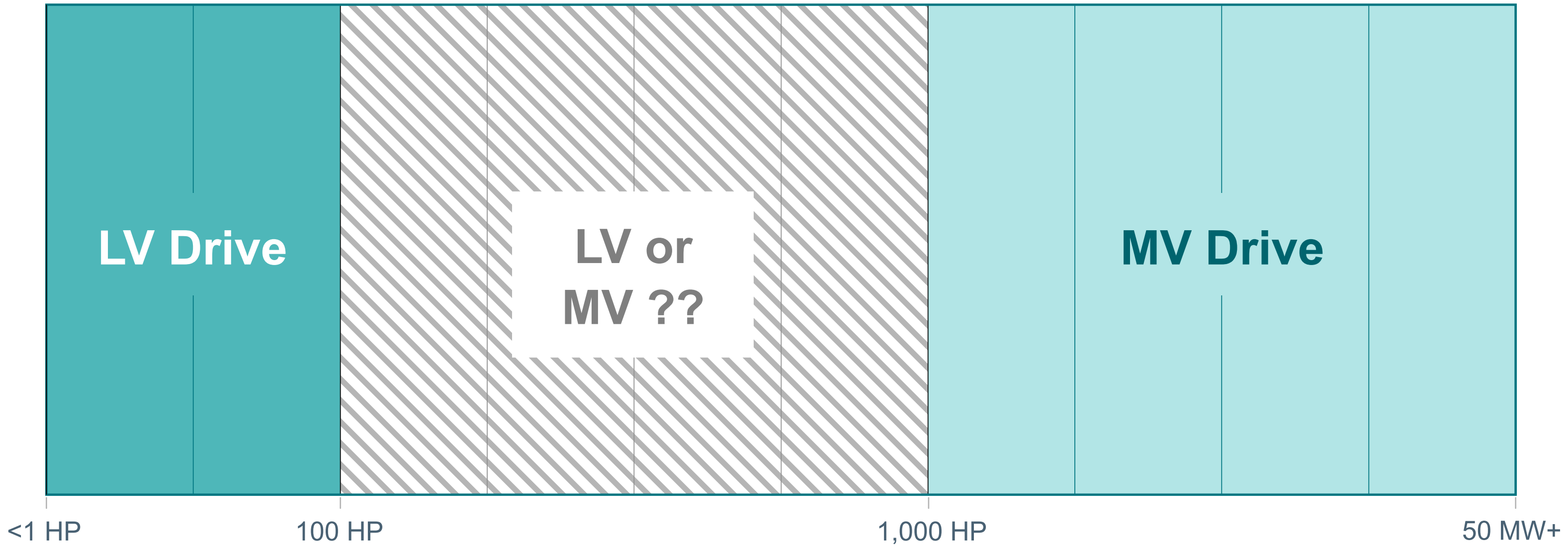
Topics

Today we will discuss how your Variable Frequency Drive (VFD) selection will

- Impact Your Plant
- Impact Your Utility Interface
- Impact Your Motor
- Impact Your System Costs

So…Where Is the Break Point Where We Switch from Low Voltage (LV)to Medium Voltage (MV) Drives?

SIEMENS



Impact on Your Plant

Cost of Installation

For loads with lower power requirements, users often consider both low and medium voltage solutions.

Available space, input voltage, existing distribution system and the distance from the distribution system to the load will play a significant role in the total cost of installation.

LV drives draw approximately 9 times the current compared to MV drives when using the same power. This requires:

- Larger and more cables per phase
- Larger and heavier cable trays or conduit
- More costly cable installation

Power Density

By utilizing products with a higher power density users will have increased flexibility when installing or replacing equipment

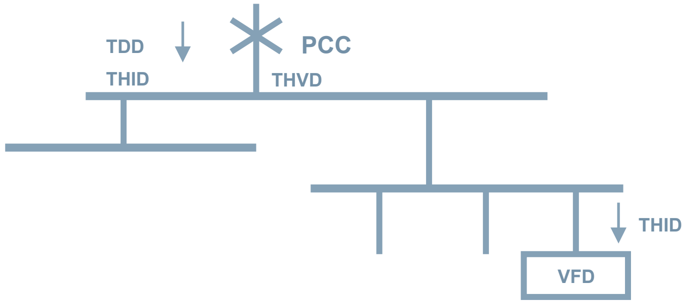
- Reduce cable and conduit costs
- Increased flexibility on placement of drive in relation to motor
- Increased system efficiency

Impact on Your Utility Interface

Harmonics IEEE 519 – 2014

IEEE 519 was developed to define limits for harmonics on supply networks

- Harmonic currents and voltages are created by non-linear (switching) loads
- Harmonic distortion can cause problems if the sum of the harmonic currents exceed limits
- Harmonics increase losses, requiring larger conductors, transformers etc., add “noise” affects other electronics users

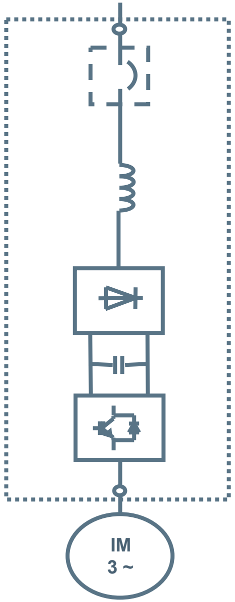


IEEE 519 limits the DEMAND distortion (TDD) and VOLTAGE distortion (THVD) at the POINT OF COMMON COUPLING (PCC). The PCC is defined as the point where the user connects to the supply.

IEEE 519-2014 Maximum Harmonic Current Distortion in Percent of I_{Load}

I_{sc}/I_{Load}	Supply Impedance	< 11	11< h < 17	17 < h < 23	23 < h < 35	35 < h	THID
< 20	>5%	4.0	2.0	1.5	0.6	0.3	5 %
20 < 50	5%-2%	7.0	3.5	2.5	1.0	0.5	8 %
> 50	<2%	10.0	4.5	4.0	1.5	0.7	12 %

Drive Topology: Basic 6-pulse VFD



For voltage source (VSI) drives:

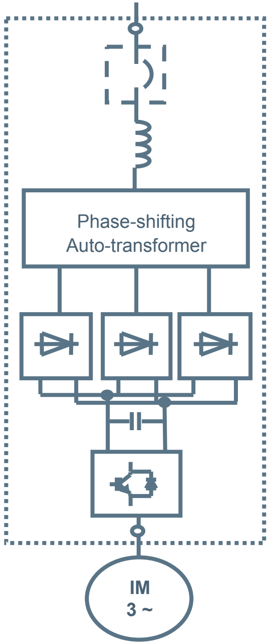
- The front end charges the DC link
- The DC link capacitor is the voltage source
- The motor side inverter controls the motor

The input line reactor reduces line side harmonics by a limited amount – higher impedance results in lower harmonics

THID at drive input terminals:
Typically approx. 40%

400 HP, 6-p drive

Drive Topology: 18-pulse LV VFD



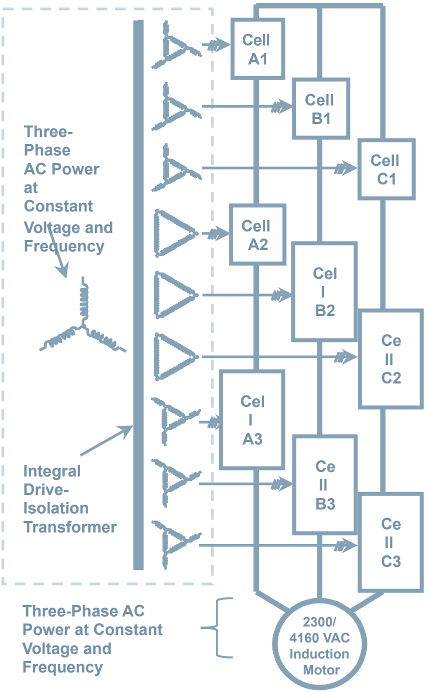
An 18-pulse LV VFD typically has:

- A phase shifting autotransformer (9 phase output) with a (high impedance) line reactor
- An 18-pulse (3x 6-pulse) rectifier

THID at input terminals of 18 pulse LV
Typically approx. 5%- 8%

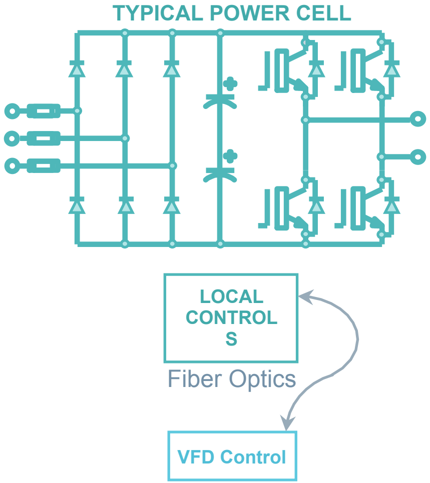
400 HP, 18-p drive with bypass

Drive Topology: 18-pulse MV VFD



An 18-pulse MV VFD typically has:

- Isolation transformer
- THID for 18-pulse drives: **Typically approx. < 5%**



600 HP, 18-p MV drive

Effects of Input Harmonics

Input distortion is the second largest cause of input power quality issues

Effects of excessive input harmonics in power bus on plant equipment:

- Standby Generator heating and possible generator trip events
- Excessive temperatures rise in motors and transformers
- Sensitive electronic equipment malfunctions
- SCADA issues
- Accelerated aging of equipment
- Tripping of circuit breakers
- Capacitor bank failure from harmonic overloads
- Cable insulation breakdown

Low voltage drives require additional measures to improve input harmonics but medium voltage drives have, at a minimum, a 12-pulse

Voltage Sags

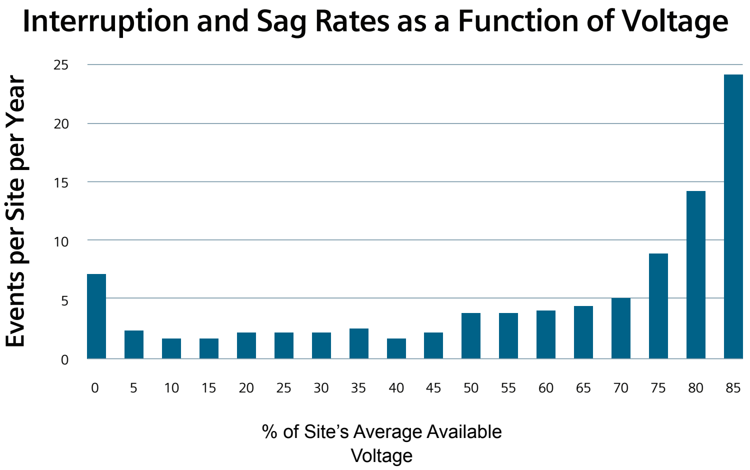
The most reported disturbances by industrial users include voltage sags and swells.

- Voltage sags account for 38% of all disturbances
- Voltage swells account for 10% of all disturbances

A facility typically experiences several events per years at an annual cost of over $75,000. These costs can include:

- Replacement of damaged equipment
- Cost of repair of failed parts
- Spoiled or off spec products
- Loss of revenue due to downtime
- Additional labor costs

Industrial users experience an average of 75 instances of voltage sag per year – in 50% of cases these events can stop a process



EPRI Report 2003

Voltage Sags

VFD PERFORMANCE COMPARISON

	6 pulse 2 level low voltage inverter	Cascaded H-Bridge medium voltage inverter
Input Line Tolerance	+10% and -15%	+10% and -10%
Voltage Sag	75% to 51% of nominal rated voltage*	80 to 65% of nominal rated voltage*
Under voltage	Depending on load's inertia 0.5 to 5 seconds*	Independent of load's inertia Continuously - drive can operate with reduced motor torque
Momentary interruption	15-16 milliseconds at full load*	80-500 milliseconds at full load*

**Defined by manufacturer*

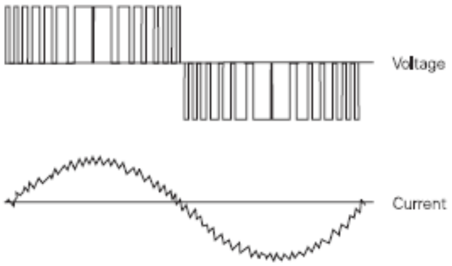
Table: Low Voltage Drive and Medium Voltage Drive Solution Performance Comparison during Input Voltage Sag

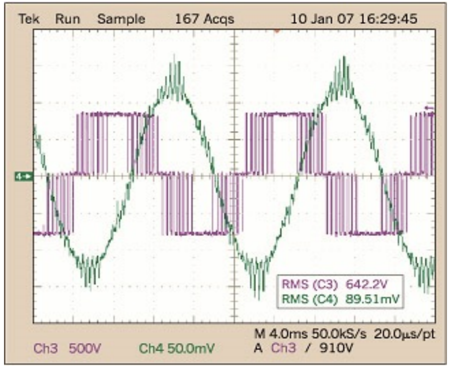
Impact on Your Motor

Output Waveforms LV and MV

LV Waveforms:

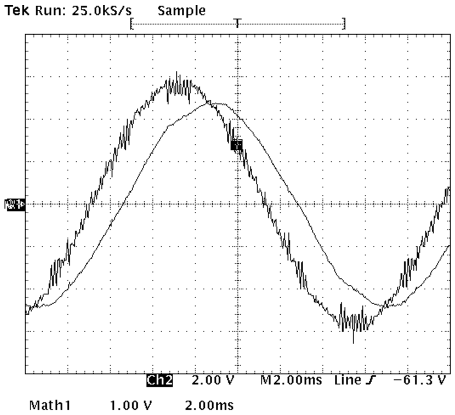
- PWM output switched from DC Link
- Higher step voltages up to 1500 Volts
- Common Mode on apps w/o magnetic isolation

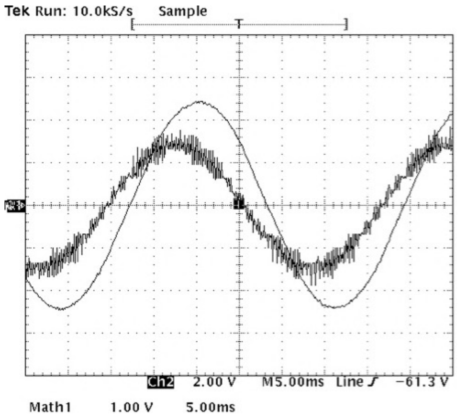




MV Waveform – Cascaded H-Bridge

- Multilevel waveform provides for cleaner output sinewave
- Reduces stress on cable and motor
- Transformer eliminates common mode voltage
- Allows for longer cable distances to motor
- Easier to retrofit into a facility with MV



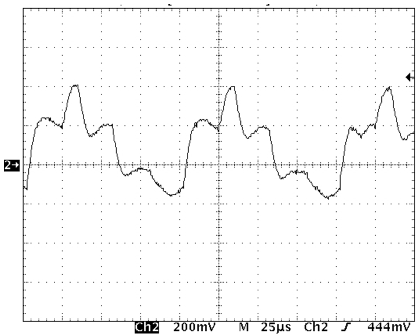


SIEMENS

Shaft Voltages and Bearing Currents

Causes of bearing currents:

- Dissymmetry in the motor magnetic circuit
- Electrostatic charge due to friction between shaft and driven load (ex. paper on rollers)
- Common mode voltages
- Fluctuation of motor neutral voltage with respect to ground



Shaft Voltage Fluctuations

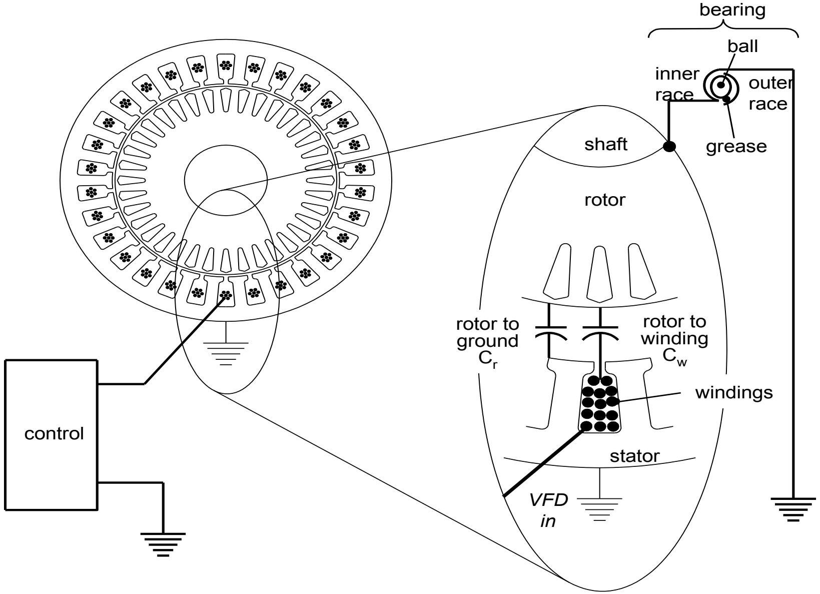
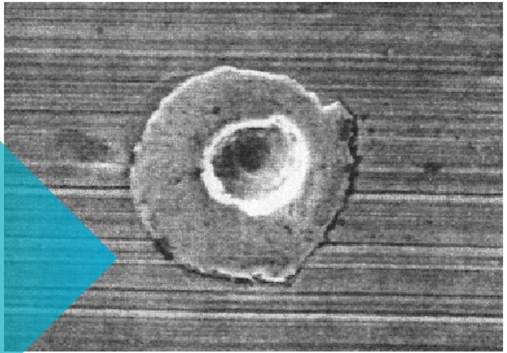
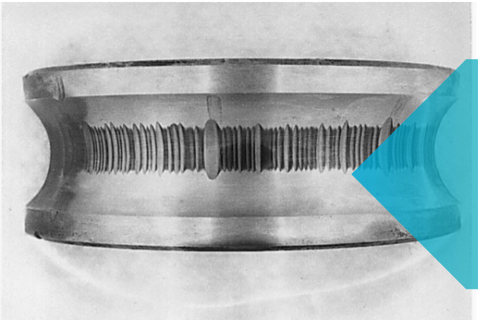


Diagram Taken From the *NEMA Application Guide for AC Adjustable Speed Drive Systems*

Shaft Voltages and Resulting Bearing Current



Electrical Arc Pit On a Bearing Inner Race Due to a Single Discharge

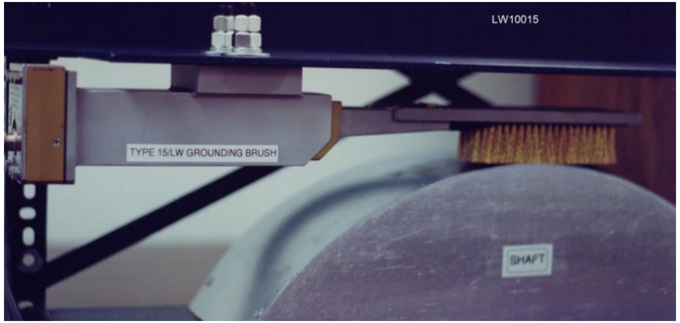


Severe Fluting of a Bearing Inner Race

Shaft Voltages and Resulting Bearing Current

Safeguards Against Bearing Currents:

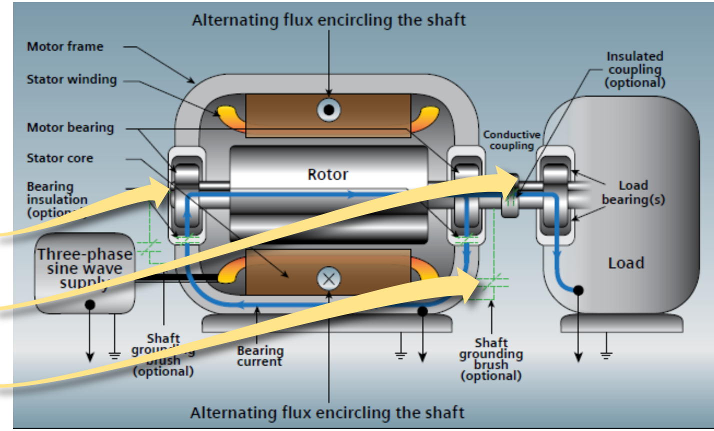
- Use a voltage or topology which reduces shaft currents
- Install an insulated bearing for classic end to end current flow
- Reduce common mode voltage/current by using a filter or solidly grounding the system
- Install shaft grounding brush

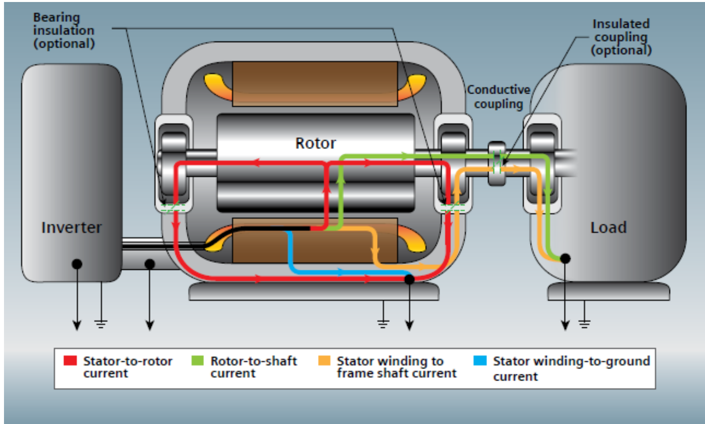


Insulated Bearing

Insulated Coupling

Shaft Grounding Brush





Impact on Your System Costs

Cable Considerations for LV

Significant Cost Factors Are from Cable and Conduit

VFD cable in LV applications:

- Utilizes 3 conductors inside single jacket
- Insulation at 600V/2 kV to protect cable
- 300% ground (to conductor) on smaller drives
- 100% ground (to conductor) on larger drives
- Shield and jacket for common mode current protection

Many LV drive suppliers suggest the usage of VFD cable

- Higher amp ratings yield larger diameter
- Extra conductors per phase yield higher line losses
  - Higher operating costs
- Higher cost for conduit
  - 80% fill rate requires derating of cable > 3 conductors
  - Many contractors install second conduit

SIEMENS

Below are the current requirements for low voltage and medium voltage

	250 HP		500 HP		750 HP		1000 HP	
Voltage	480 V	4160 V	480 V	4160 V	480 V	4160 V	480 V	4160 V
Current	**313 A**	**32 A**	**590 A**	**65 A**	**890 A**	**95 A**	**1370 A**	**130 A**

Side by side comparison of cable size and number of conduits required

HP	Cable Size		# of Conductors	
	480 V	4160 V	480 V	4160 V
250	3/0	#4	2	1
500	4/0	#1	4	1
750	373 MCM	3/0	5	1
1000	535 MCM	250 MCM	5	1

Cable Comparison Analysis LV and MV

SIEMENS

Cable Feet 200

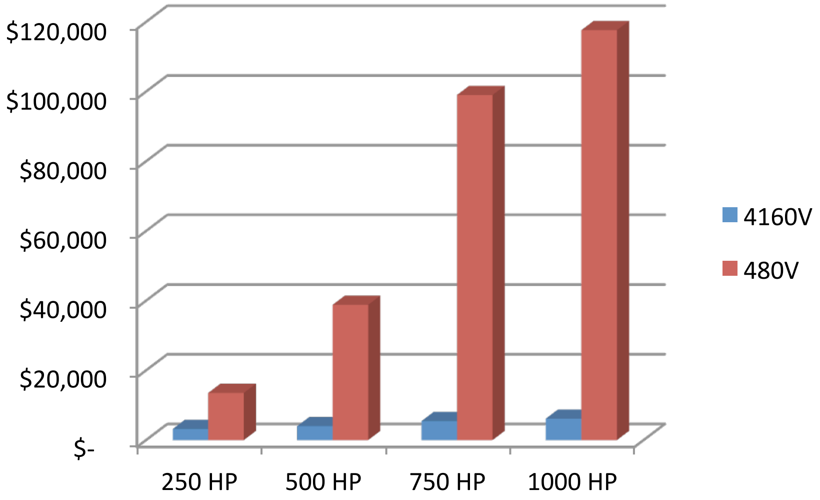
480V										
HP	**Enclosed (NEMA 1) Output Reactor**	**Cable Size 3 phase**	**3 Conductor Cable/# of Conductors per phase**	**Inv. Duty VFD Cable $ Per Foot, 3 Ph**	**Cost at Length**	**Conduit Size – inch**	**# of Conduit**	**Installed cost per ft**	**Conduit Cost at length**	**Total Cost Cable & Conduit**
250	$630.63	3 /0	2	$19.21	$7,684.00	2	2	$39.75	$5,840.00	**$13,524.00**
500	$1,249.05	4/0	4	$22.60	$18,080.00	2.5	4	$39.75	$20,720.00	**$38,800.00**
750	$3,651.90	373 MCM	5	$64.56	$46,716.00	3	5	$39.75	$23,850.00	**$99,010.00**
1000	$3,458.70	535 MCM	5	$77.86	$77,860.00	4	5	$39.75	$39,750.00	**$117,610.00**
1500	$6,792.24	535 MCM	9	$77.86	$109,004.00	4	9	$39.75	$55,650.00	**$221,058.00**

4160V										
HP	**Enclosed (NEMA 1) Output Reactor**	**Cable Size**	**# of Conductors single phase**	**5 kV Cable $ Per Foot**	**Cost at Length**	**Conduit Size - inch**	**# of Conduit**	**Installed cost per ft**	**Conduit Cost at length**	**Total Cost Cable & Conduit**
250	N/A	#4	3	$1.54	$924.00	1.25	1	$11.25	$2,250.00	**$3,174.00**
500	N/A	#1	3	$2.87	$1,722.00	1.25	1	$11.25	$2,250.00	**$3,972.00**
750	N/A	1/0	3	$4.89	$2,934.00	1.5	1	$12.45	$2,490.00	**$5,424.00**
1000	N/A	4/0	3	$5.37	$3,222.00	3	1	$14.60	$2,920.00	**$6,142.00**
1500	N/A	500 MCM	3	$8.63	$5,178.00	4	1	$25.90	$5,180.00	**$10,358.00**

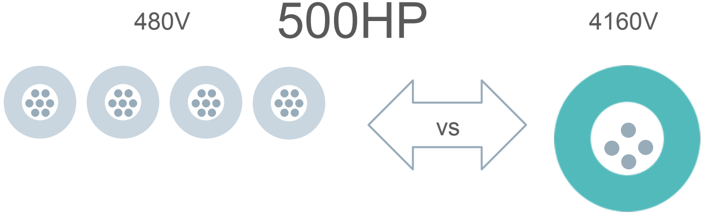
Source: RS Means Cost Data 2016

Conduit Considerations

Total Cost Comparison – 480V vs 4160V



Number of Conduits for 500HP



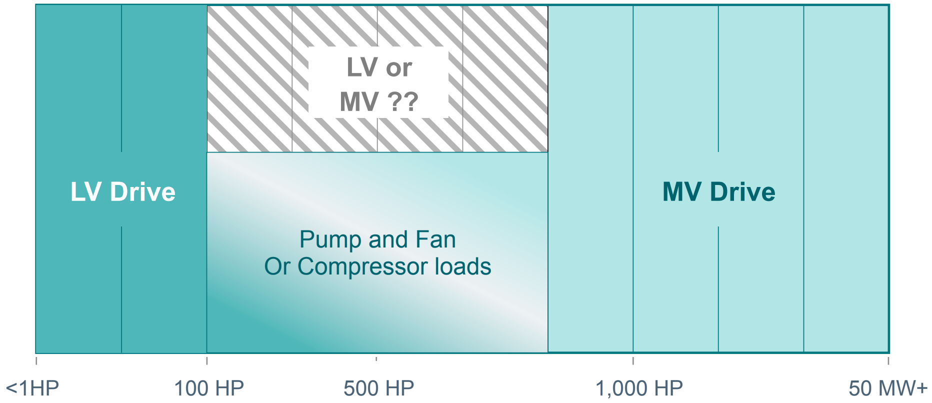
$38,800.00

$3,972.00

So Where Is the Break Point Where We Switch from MV to LV Drives?

Key Decision Factors:

- Existing LV or MV system with extra capacity available?
- Minimization of Unit Substations for cost and efficiency
- Price is a factor – not just the VFD, but the complete system
  - Motor cable cost
  - Conduit and Installation cost factor
  - Lifetime operating cost
  - Minimize line losses for greater efficiency
  - Footprint



SIEMENS
Ingenuity for life

A New Paradigm Opens

Replacing Low Voltage, Low Power Drives with Medium Voltage Solutions

Contact Page

Karl Heideck
Principal Business Developer

100 Hunt Valley Road
New Kensington, PA

Phone: +1 678 300 8758
Mobile: +1 678 300 8758

E-mail:
karl.heideck@siemens.com

siemens.com

Questions?