

Cost Considerations When Selecting Variable Frequency Drive Solution

Introduction

Advancements made in the development of drive technology mean users have more options than ever when selecting a drive system. Low voltage (LV) variable frequency drives (VFDs) have been applied to applications up to 2500 horsepower (HP) and greater. Medium voltage (MV) VFDs have been applied to applications as low as 150 HP. Traditional power system design practice suggests that the motor crossover from low voltage to medium voltage is in the 200 to 600 HP range. A recent industrial customers' survey conducted in 2016 shows that some customers are beginning to consider switching from a LV to a MV solution as low as 100 HP.

Percentage of Drives by Power that Customers Switch to MV over LV Drive

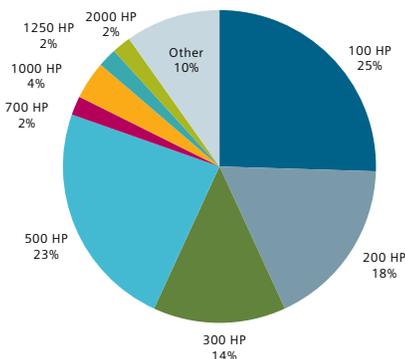


Figure 1
Source: 2016 Industrial Customer Survey

No two applications are the same, and this means that where there is more than one possible solution, the best strategy is to conduct a cost-benefit analysis of the various options. Frequently, consideration in choosing a drive is the initial capital cost. However, to calculate the true cost of a drive over its entire life cycle a number of other factors need to be taken into account. Some considerations that may steer the decision towards a LV or MV solution are clear and straightforward:

- Available Input Voltage: the choice to install a medium voltage or low voltage solution is sometimes decided by the system bus: when there is 4000 V bus with multiple MV motors, a MV solution might be easy to integrate and this would provide a more cost effective solution.
- Existing Distribution: if there is an existing 480 V service capable of handling the additional load, it may be cost prohibitive to install an additional service at 4160 V for one or two large motors.
- Electrical Room Size: when the project is a retrofit or an upgrade, space availability is critical. Medium voltage equipment typically takes more floor space and requires greater working clearances in an electrical room.

If the room needs to be modified to create more space, it could have significant cost implications, or prohibit the installation entirely. Approach Boundaries listed in NFPA 70E are increased from 480 V to 4160 V (see Table 1).

There are other factors that are important to consider during evaluation. Additional analysis is required to understand the cost impact on installation and application. They include, but are not limited to: harmonics, input line quality, distance between drive and motor, and system efficiency. Most costs discussed in this paper can be grouped into the following categories:

- Cost of equipment: drive vs system
- Cost of operation: efficiency
- Cost of installation: cable length and output filters
- Cost of power quality: equipment ability to withstand input power fault conditions
- Cost of input harmonics: equipment sensitivity to input harmonics

The comparison and discussion in this paper will be based on the SINAMICS PERFECT HARMONY GH180 medium voltage drive manufactured by Siemens and a basic 6 pulse and 18 pulse low voltage drive and their possible configurations.

	480 V	4160 V
Limited	3'6"	5'0"
Restricted	1'0"	2'2"
Prohibited	0'1"	0'7"

Table 1: NFPA 70E Boundaries for Low Voltage and Medium Voltage Equipment

System Cost Comparison: High-Low-High Solution

The cost of a low voltage AC drive can be as little as 50% to as much as 105% when compared to the cost of a medium voltage AC drive – it all depends on site conditions and requirements. However the initial purchase price of the drive is only part of the equation. When the costs for components, cabling and installation, and efficiency are included, the economic advantages of the two drive options may not be as apparent.

Low voltage drives have been positioned as an alternative, cost competitive solution to medium voltage drive when using medium voltage motors at lower power ratings. This solution in industry is known as High-Low-High and there are two instances where this exists. The first case is where there is an existing MV motor that runs directly on line and the desire to install a VFD to improve system efficiency exists. The second case is used on a specific application in the oil and gas industry for Electrical Submersible Pumps (ESP). Low voltage drives will require an

input transformer to step down input voltage to 460-600 V. If the existing motor is medium voltage, it will need a step-up transformer from 460-600 V to the medium voltage of the motor.

As power electronics continue to develop, the size of medium voltage drives have become significantly smaller over the past several years. The figures below show the footprint advantage that MV solutions, like the SINAMICS PERFECT HARMONY GH180 offers over standard low voltage drive implementation. The total footprint, including all components in High-Low-High solutions, can be as much as 300" (See Figure 2). The standard dimensions for a 6-pulse drive is: width and depth 40"x 34," while a medium voltage drive with integral transformer and 18-pulse configuration is W48"xD40". When comparing these solutions side-by-side, the total footprint of the SINAMICS PERFECT HARMONY drive is approximately six times smaller when compared to a standard High-Low-High configuration.

The charts below represent relative price comparisons of various VFD solutions for low power medium voltage motors. The solutions are:

- 6-pulse low-voltage drive with step-up transformers
- 18-pulse low voltage drive with input and step-up transformer
- 18-pulse medium voltage drive

The data shows that at 250HP, the medium voltage drive is comparable to the 18-pulse low voltage solution in High-Low-High applications (See Figures 3 and 4). As power of the medium voltage motor increases, the advantage of MV over LV continues to increase to the 6-pulse design as well. Medium voltage drives now offer users significant cost advantages when compared to low-voltage solutions, particularly in high-low-high applications.

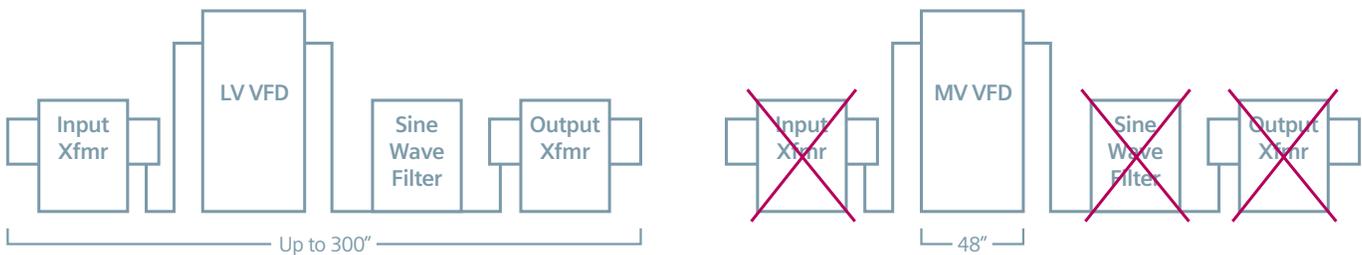


Figure 2
High-Low-High Solution vs. MV Drive Solution

250HP VFD Solution Cost Comparison

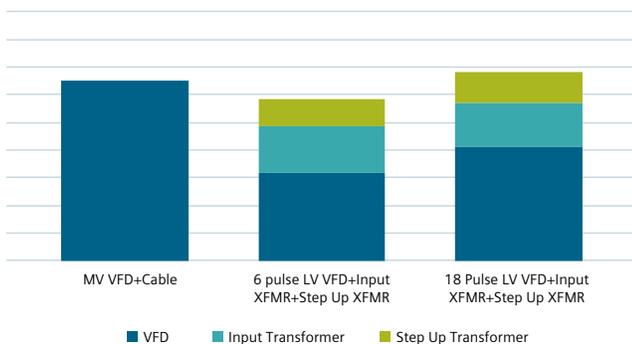


Figure 3

500HP VFD Solution Cost Comparison

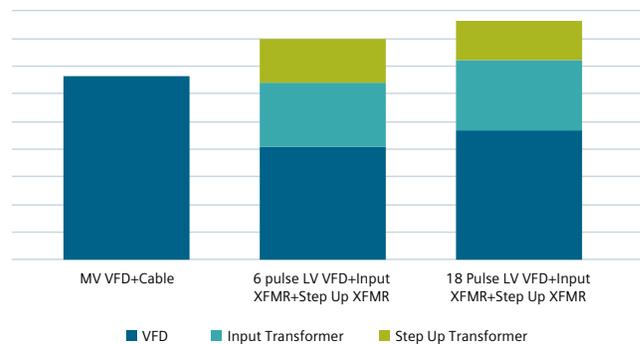


Figure 4

System Efficiency

	6 pulse LV Losses	18 pulse LV Losses	GH180 6SR520 MV Losses
VFD	2.0%	3.0%	3%
Input filter	0.5%-1.0%	0%	0%
Input Transformer	2.0%	2.0%	0%
Output Transformer	2.0%	2.0%	0%
Output Sine Filter	1.0% - 2.0%	1.0% - 2.0%	0%
Total Losses	7.5 - 9.0%	8.0 - 9.0%	3%

	6 pulse LV Solution	18 pulse LV Solution	18 Pulse MV Solution
Total Efficiency	92.5% - 91%	92% - 91%	97%

Table 4: Side by Side Comparison of Typical Efficiencies of Various Configurations

	LV Drive System 92% Efficiency	GH180 6SR520 97% Efficiency	Savings MV vs LV solution		
	1 year cost	1 year cost	1 year	5 years	10 years
250 HP	\$12,340	\$6,790	\$5,550	\$27,750	\$55,500
500 HP	\$21,800	\$11,760	\$10,040	\$50,200	\$100,400

Table 5: MV Drive Savings over Time

The driving force behind the increased use of VFDs is the energy savings it provides. Table 4 compares system efficiency for LV and MV solutions. This comparison is specifically looking at high-low-high solutions. When efficiency is taken into account medium voltage offers a preferred solution. In 10 years, users can save as much as \$100,000 in electricity costs alone for a 500 HP solution.

The savings by using a more efficient solution is represented in the table below. The key assumptions are:

- Average Price of Electricity to Industrial Customers - 0.07 \$/kWhr
- Average Distribution charge to Industrial Customers - 0.03 \$/kWhr

Cost of Installation – Cables and Output Filters

During upgrades and expansion projects, for the loads with lower power requirements, users often consider both medium voltage and low voltage solutions. The available input voltage, existing distribution system, and the distance from the distribution system to the load location will play a significant role in the total cost of installation. A major advantage with MV drives when compared to LV drives is lower current flow for a given power output. LV drives draw about 9 times the current compared to MV drives when using the same power. This means that a LV VFD requires larger and more cables per phase, larger and heavier cable trays or conduit, resulting in a more costly cable installation. Cable size and cost vary with the level of current being conducted: the higher the current, the larger the cable and the greater its cost. Tables 2 and 3 show the differences between the two solutions.

The cable cost difference between the 480 V and the 4160 V VFD solutions grows disproportionately as the motor current increases. At 100 feet of cable (see Figure 5), the cost for 250 HP low voltage drive is 10 times the cost of medium voltage cable for the same power. Costs are 12 times higher for the 500 HP drive and 24 times higher for 750 HP and 1,000 HP drives. The distance between the power source, the VFD and the motor has a big impact on cable costs as well. As distance increases so does the cost: the cost of low voltage cables can be at least double when comparing distances of 100 feet versus 200 feet. Additional costs not referenced in the charts that follow are in the form of cable trays and labor. As the number of cables required increases contractors will favor the use of two cable trays to reduce derating requirements but this also increases the cost of installation.

As distance between the LV VFD and the motor increase, the cost of cables is not the only concern: the drive may also require an output filter. Low voltage VFD's have two level output voltage wave forms. This output waveform contains significant 5th and 7th order harmonics that cause torque pulsations at six times the fundamental frequency, creating stress on the motor and load. In addition to torque pulsation, the long feeding cable can cause resonance at the motor terminal due to impedance mismatch between the cable and motor. When resonance occurs, large voltage spikes are present at the motor which can damage the insulation and shorten its operating life. Most LV drive manufacturers recommend an output filter when the cable length between the VFD and motor exceeds 150 ft.

	250 HP		500 HP		750 HP		1000 HP	
	480 V	4160 V	480 V	4160 V	480 V	4160 V	480 V	4160 V
Current	313 A	32 A	500 A	65 A	911 A	100 A	1200 A	130 A

Table 2: Current Requirements for Low Voltage and Medium Voltage Drives for the Same Power

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

Table 3: Side by Side Comparison of Cable Size and Number of Conductors Required

***Notes:**

1. Inverter Duty VFD Cable was used for LV drive and Standard Cable for MV drive
2. NEC Table 310.15(B)(3)(a)
Adjustment factors for more than 3 current carrying conductors:
4-6 Conductors @ 80%; 7-9 Conductors @ 70%; 10-20 Conductors @ 50%
3. Ampacities taken from NEC table 310.15(B)(3)(a)
4. The cost does not include cable tray or installation cost

Cable Cost Comparison by Power, 100ft

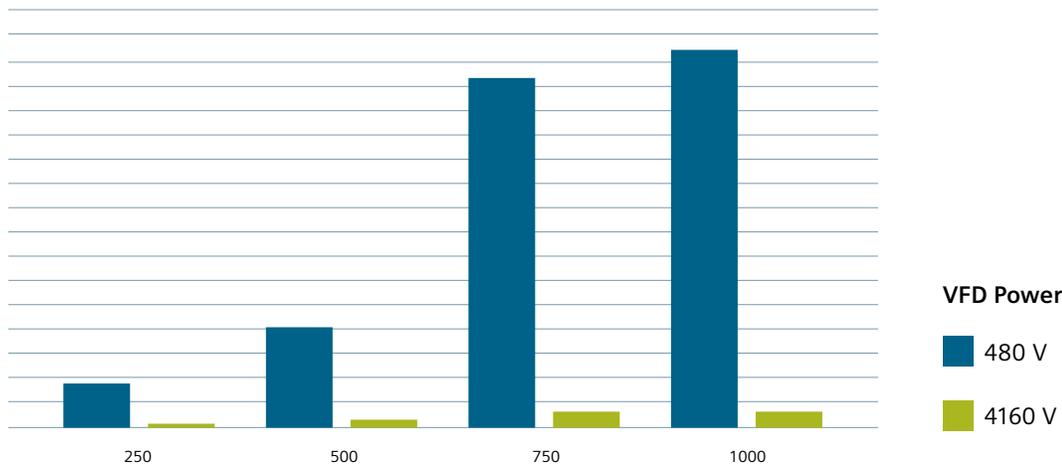


Figure 5

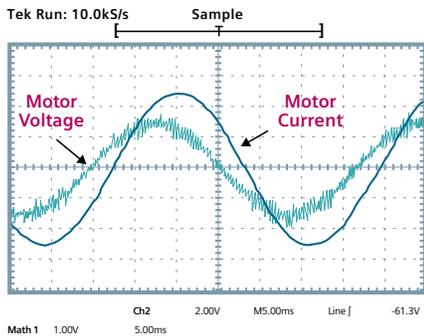


Figure 6
SINAMICS PERFECT HARMONY Output Waveform

Certain medium voltage drives, such as Siemens SINAMICS PERFECT HARMONY drives, have inherent, almost sinusoidal output voltage waveform (See Figure 6), low harmonics and negligible torque pulsations:

- Less than 1% VFD induced Torque Ripple for any given frequency: no motor heating and no bearing wear
- 13 level output waveform line to line and Small output voltage steps (1.3kV) - no voltage spikes at the motor
- No need for filters up to 7500ft (2.3km)
- Waveforms remain high quality at lower speeds due to multi-level PWM output

Cost of Power Quality

The financial impact of poor power quality is often underestimated or poorly understood because they are typically reported as maintenance issues or equipment failures. The true economic impact is often not evaluated - especially when power quality halts a process. A US study² determined that the economic cost of power outages and power quality disturbances across all U.S. business sectors is between \$120 and \$190 billion per year. In Europe, according to the report,³ this type of cost exceeds \$167 (€150) billion annually.

Power quality (PQ) is defined as the grid's ability to provide a clean and stable power supply. It is always available, noise-free and within voltage and frequency tolerances. Fluctuations in the electrical supply in the form of momentary interruptions, voltage sags or swells, transients, harmonic distortion, electrical noise, and flickering lights, reduce power quality. Fewer such incidents indicate greater power quality.

The most reported disturbances (See Figure 7) by industrial customers include voltage sags and swells with sags accounting for 38% and swells representing 10%, followed by harmonics with 22%.¹ Most of the existing grid in the USA was built 30-50 years ago⁵. Due to aging, PQ events are even more relevant today and in some instances are on the rise.⁴ There are several causes behind voltage sags and power outages (See Figure 8). Some are generated by the site itself: start-up of large loads, utility switching or utility equipment failure and bus transfers; others are related to weather, construction, traffic or animal accidents.

The study states that digital economy and process industries combined lose \$1 billion per year due to power quality issues. This number excludes cost of interruptions. Impact varies from industry to industry when measured in terms of costs per kW of the plant load size. Power quality issue costs range from \$3-\$8 per kW for the textile industry to \$15-\$20 per kW per event for industries like metals and chemicals (See Figure 9). Cost impact depends on each plant and industry product and cost of inputs. Since a facility typically experiences several events per year, the annual cost, due to sags, is often over \$75,000. These costs can include:

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

Industrial customers experience an average of 75 instances of voltage sags per year² – in 50% of the cases these events can stop a process. Figure 10 represents average number of events per site, per year – voltage sag of less than 10% are considered normal. Most of the recorded events were minor sags, though the average site also experienced about 9 momentary or longer service interruptions per year (available voltage between 0 and 10% is considered interruption). Whether your process stays online during a power quality event depends on your site equipment operating envelope and tolerances.

Frequency of Power Quality Problems at Customer Sites

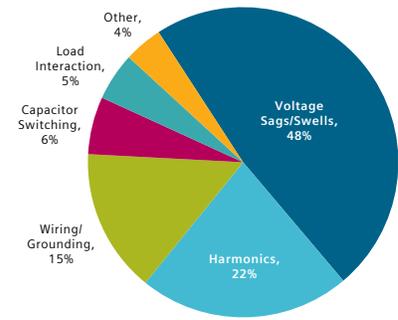


Figure 7
Source: EPRI Report, 2003

Major Causes of Power Outages in the U.S.

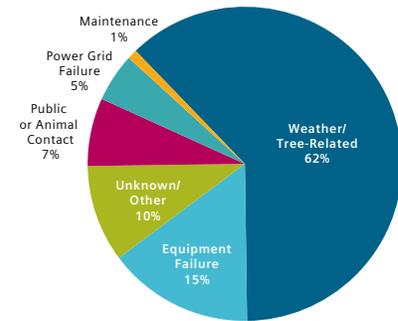


Figure 8
Source: Edison Electric Institute

Cost of Power Quality, \$/kW per Event (Total Plant Load)

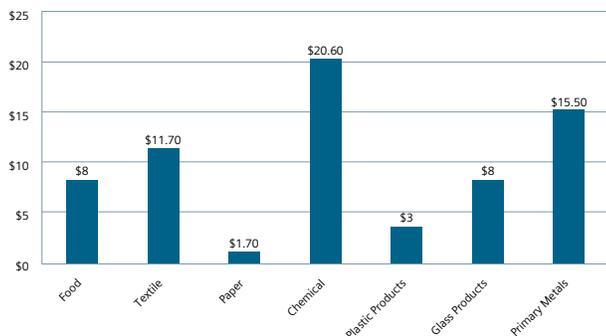


Figure 9
Source: EPRI Report, 2003

Interruption and Sag Rates as a Function of Voltage

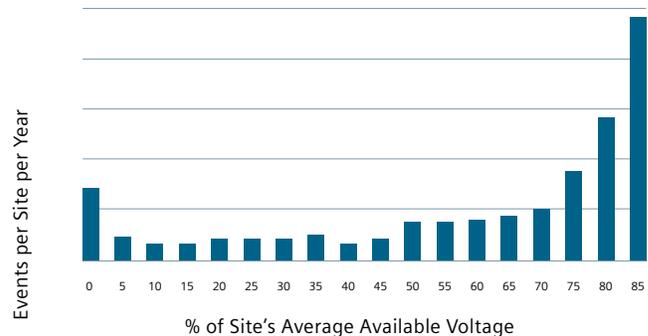


Figure 10
Source: EPRI Report, 2003

	Low Voltage Drive 6 pulse	PERFECT HARMONY GH180 6SR520
Standard Input Voltage Tolerances	+10% / -15%	+10% / -10%
Voltage Sag duration is up to 1 minute Undervoltage lasts longer than 1 minute VFD Performance	<ul style="list-style-type: none"> DC bus capacitance in VFD allows for minor sag compensation (ex: 80 ms (5 cycle) sags at 70% available voltage)⁷. Some manuals state operation at 85% for up to 1 minute <ul style="list-style-type: none"> Voltage drop below these tolerances results in drive's ride through mode The drive's dc bus will usually trip on undervoltage at an equivalent line voltage of 65% of nominal rated voltage (the trip level varies from manufacturer to manufacturer some offer as lows 51%) 	<ul style="list-style-type: none"> VFD output power is rolled-back linearly from 100% power @ 90% input voltage down to 50% power @ 65% input voltage <ul style="list-style-type: none"> Output power is reduced by limiting the available motor torque The VSD can operate continuously in this mode Voltage drop below 65% results in drive's ride through mode
Input Power Loss Ride Through	<p>Input Voltage Falls Below 65%</p> <ul style="list-style-type: none"> Manufacture manuals state: the dc bus can deliver full power to a load for about one cycle or 15-16 ms (1 cycle) by allowing itself to decrease from its nominal voltage. It may be shorter due to load conditions and motor speed. If the combination of the load's inertia and energy stored on the bus are inadequate to prevent the bus from tripping, the drive will use an automatic restart function to recover. 	<p>Input Voltage Falls Below 65%</p> <ul style="list-style-type: none"> The VFD will "ride-through" without tripping for 80 ms (5 cycles) minimum and up to 500 ms (30 cycles). During "ride-through" the motor voltage is maintained but no torque is produced until input VFD voltage is re-established. An automatic restart and spinning load functions are available to catch and restart motors when the motor flux has collapsed during the line outage.

Table 6: Low Voltage Drive and Medium Voltage Drive Solution Performance Comparison during Input Voltage Sag

Cost of Input Harmonics

Input harmonic distortion was identified as the second largest cause of input power quality issues. These harmonics are related to the increasing use of non-linear loads such as computers, AC and DC variable frequency drives, uninterruptible power supplies, static VAR compensators, or any device with a solid state AC to DC power converter. Harmonics are a form of voltage or current waveform distortion. A recent study in the U.S. shows that the level of harmonics in a distribution system continues to increase over time: 60% of all circuits in the project showed an increase in harmonics. The range of increase was 3% per year or 30% over 10 years, for example: 2% THD in 2005 increased to 2.6% THD in 2015⁴.

Several studies in the USA and Europe identified harmonics as a contributor to economic loss. A study of industrial users in the European Union found that input harmonics were responsible for about 5% of all power quality costs or \$8.4 (€7.5) billion annually.³ When

compared to voltage sags, very rarely does harmonics distortion lead to a process interruption. The majority of the costs are attributed to process slow down (ex: small errors, minor nuisance tripping or loss of synchronization and increased error rate). According to the report, 25% of the harmonic costs were related to equipment, either in the form of damage or additional maintenance. The list below highlights the effects of excessive input harmonics in the power bus on plant equipment:

- Excessive temperature rise in motors and transformers
- Sensitive electronic equipment malfunctions
- SCADA issues
- Accelerated aging of equipment
- Tripping of circuit breakers
- Capacitor bank failure
- Cable insulation breakdown

There is another cost that is not related to the equipment. In the USA, a utility typically specifies harmonic current limits in their contract with a customer and when the level of harmonics exceeds IEEE519 recommendations at the Point of Common Coupling between a utility system and a customer, the utility issues a fine. Most customers have filters at this point but the system may need to be reevaluated if there is new equipment that introduces additional harmonics.

Using a 6 - pulse LV drive configuration produces high input harmonics if not corrected. One of the most common solutions used by many low voltage drive manufacturers is to place an input line reactor (3% to 5% impedance) between the drive and the power supply. Table 7 shows methods to reduce input harmonics content that a VFD creates and the level of distortion as a result of mitigation.

Technology	Total Harmonic Distortion (THDi)
6-Pulse Low Voltage VFD	50-70%
6-Pulse Low Voltage VFD with Reactor	35-45%
6-Pulse Low Voltage VFD with Passive Filter	6-10%
6-Pulse Low Voltage VFD with Active Filter	3.5-5%
12-Pulse Low Voltage VFD	10-14%
18-Pulse Low Voltage VFD	4-6%
Active Front End Low Voltage VFD	< 5%
18-Pulse Medium Voltage VFD SINAMICS PERFECT HARMONY GH180 AC	
	< 5%

Table 7: Mitigation techniques to reduce input harmonics and their effectiveness

Table 7 identifies various solutions to mitigate harmonic distortion. As effectiveness of the solution to reduce input harmonics increases so does the costs associated with it (See Figure 11). When considering the best fit for an application, one should remember that the total cost of the system will include not only VFD and accessories costs, but also installation, maintenance, footprint and hauling costs. To obtain the best overall harmonics mitigation solution, the user must view the system as a whole circuit and evaluate different mitigation methods to prevent a power quality concern. In North America, the IEEE 519-2004 standard provides recommended limits for individual harmonics and total distortion.

While low voltage drives require additional measures to improve input harmonics, medium voltage drives have, as a minimum, a 12-pulse diode rectifier configuration due to the high DC voltage requirement. Drives come in a range of pulse counts depending on the manufacturer (12 to 36 pulse configurations). In many cases, the number of pulses is driven by the drive topology and design. In order to meet IEEE 519, an 18-pulse configuration with phase shifting transformer is required, at the same time it also offers an optimized cost benefit solution.

For example, SINAMICS PERFECT HARMONY GH180, 9 cell, 18-pulse configuration waveform (see Figure 12) meets the most stringent requirements for voltage and current harmonic

distortion, even if the source capacity is no larger than the drive rating.

It provides:

- Less than 3% total voltage distortion
- Less than 5% total current distortion

18-Pulse, Multi-Level PWM

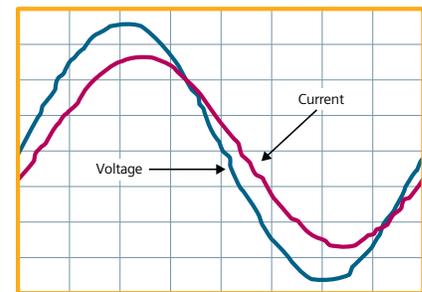


Figure 12

Low Voltage Drive Input Harmonic Mitigation Relative Cost Comparison

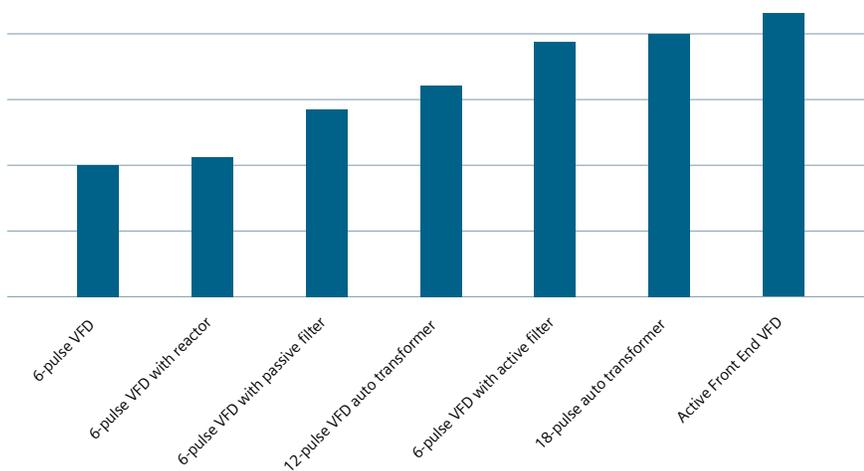


Figure 11

Case Study: Use of Low Voltage and Medium Voltage solution in Electrical Submersible Pump (ESP) Application

Historically, low voltage drives have dominated in ESP applications but recently more and more users are considering and using medium voltage drives. According to industry publications, somewhere around 90% of all oil wells require some form of artificial lift to improve oil flow. ESPs are one of several methods used in this industry. Once the oil reservoir stops producing oil under free flow, electrical submersible pumps are used to pump the oil to the surface. Over time the field conditions change and so does the requirement for motor power. An ESP is a centrifugal pump driven by a medium voltage electric motor that ranges from 1000 V to 4800 V.

Electrical submersible pump applications create certain motor design limitations: they are compact in nature to be able to fit in a tube located in a well bore; the level of insulation available is lower when compared to conventional motor designs, and frame parameters cannot be increased to handle mechanical stresses. To achieve different horsepower ratings, the motor modules are required to be connected in series.

In addition to space restrictions there are operational ones as well. These pumps must be capable of pumping a combination of oil, water, brine and gas. To reduce wear, the motor requires special abrasion-resistant bearings. This process generates high heat and in order to run the motor in this environment it is typically filled with refined dielectric oil to provide bearing lubrication and thermal conductivity. More often than not, ESPs are installed in remote locations. The power is more susceptible to disruptions from outages, poor voltage regulation, and transient voltage

conditions. These design, operational and site constraints make these motors sensitive to the following conditions:

- Input line overvoltage and transient spikes
- High inrush torques
- High dv/dt and
- Torque pulsations

The ESP failures have a very high cost. The average ESP run-life is between 2 and 2.5 years but the trend in the industry is to increase it to 5 years in order to reduce the cost of the field. The total cost to an end-user of one ESP failure is about \$133K¹³. Below is the breakdown of the average cost associated with the Onshore ESP operation of 100 wells:

- Average loss of revenue \$45x200x7=\$ 63K based on:
 - » price per barrel - \$45 (can be as high as \$100 depends on market conditions)
 - » average oil production per well: 200 bopd (barrels of oil per day)
 - » average workover & waiting time: 7 days
- Average intervention cost: \$20K (maybe higher depending on a cost and availability of a rig)
- Average equipment cost: \$50K

According to an ESP Reliability Information and Failure Tracking System project, the top three ESP components that fail in the first 90 days are: motor, followed by cables and pumps. Over time motors also show increasing trend for failure rate compared to other components. Short-circuited motors and cables are the most severe mechanisms of early ESP failures (See Figure 14)¹⁴. The reason for short circuit events is insulation break down. As has been stated in this paper, LV drive solution, if

not properly selected and engineered, may produce high output voltage spikes that lead to insulation break down of both cable and motor.^{10, 15}

Based on challenging design, operation and site conditions of ESP applications SINAMICS PERFECT HARMONY GH180 provides the best solution for this application. Siemens has already installed over 700 GH180 units globally in this application alone. The drive's robust input line performance, low input harmonic content and sinusoidal output voltage waveform without need of an output filter for motor cable lengths up to 7500ft promotes longer cable and motor life. In addition, the SINAMICS PERFECT HARMONY GH180 drive provides the following benefits when compared to a LV solution:

- No step-up transformer needed, the drive has direct feedback from the motor
- No restriction on starting torque - 100% of torque is available at 1.6Hz speed
- When pump gets stuck due to sediment collection at the bottom – to free the motor the drive can produce 150% of rated torque required without the need of a rocking start reducing stress on motor
- To ensure fault free operation the drive can be programmed to run without output ground fault
- Short Power Loss Ride through at least 5 cycles (80 ms) to provide trip free operation during system bus reclosure events
- In locations that have frequent lightning storms the drive offers standard lightning arrestors to provide protection to drive, cables and motor

ESP – Primary Failed Items – Early Failures

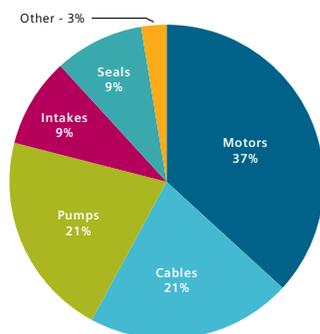


Figure 13
Source: ESP-RIFTS Report, 2009

Most Severe Failure Mechanisms – Early Failures

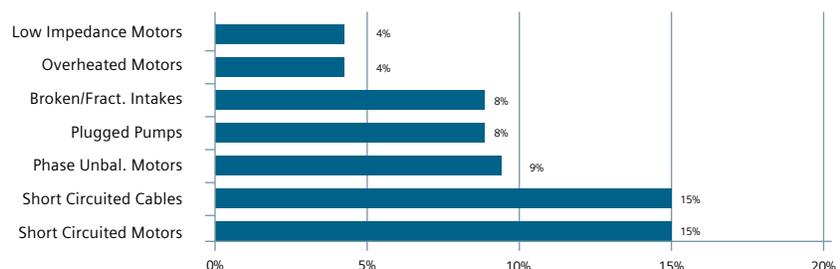


Figure 14
Source: ESP-RIFTS Report, 2009

Key Takeaway

Medium voltage drives provide users with optimal performance and a cost effective solution when compared to typical low voltage drive systems.

- The size and cost of medium voltage drives continues to improve, when compared to High-Low-High solutions offered by low voltage drives.
- Medium voltage drives have clear price and system advantages when used with motors rated at 250HP and above.
- Medium voltage drive solutions improve operating efficiency of High-Low-High configurations up to 5%. The energy savings contributes to the user's bottom line.
- Reduced cabling cost: low voltage cable cost compared to medium voltage cable can be as high as 10 times and up to 24 times more expensive for the same power. The use of medium voltage cables reduces material and installation cost associated with the traditional LV solution.

- For applications and locations that require cables longer than 150ft, a medium voltage drive offers the best solution when compared to LV drives. For example, a Siemens SINAMICS PERFECT HARMONY drive can be applied on motor applications with distances up to 7500ft (2.3 km) without any filters.
- Medium voltage drives, specifically the SINAMICS PERFECT HARMONY drive, can offer users flexibility with simplified and optimized system:
 - » Built-in input transformer - input voltages ranging from 480 volts up to 6.0 kV
 - » No need for output filter
 - » No need for step up transformer - output voltage ranging from 1.8 kV volts up to 4.0 kV
- Robust design provides immunity from most input power disturbances and interruptions to ensure protection of user equipment and trip free operation during most common and frequent power quality issues:
 - » Best in Class Input Voltage Brownout Conditions - no trip down to 65% of nominal voltage
 - » Input Power Loss Ride Through up to 500 msec
 - » Built-in input transformer with lightning arrestors
- A medium voltage drive is able to meet IEEE519 requirements with built-in 18 pulse configuration with phase shifting integral transformer while typical 6 - pulse low voltage drive needs additional equipment to achieve similar results.

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