WEB: SPOCAUTOMATION.COM
PHONE: 844.SPOC.VFD OR 844.776.2833
EMAIL: SALES@SPOCAUTOMATION.COM

SPOC AUTOMATION

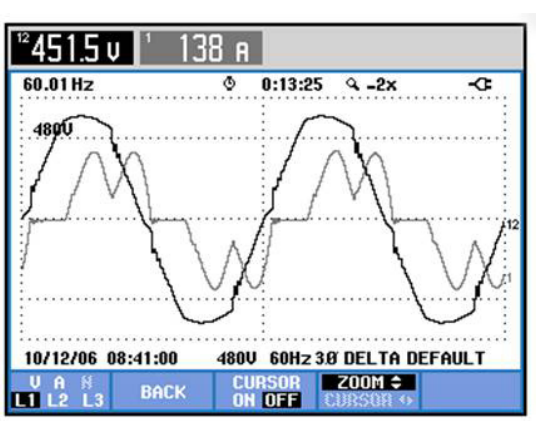
Cancel Harmonics Using an Active Front End Drive

Increase efficiency, decrease maintenance costs, improve power quality upstream and across the distribution

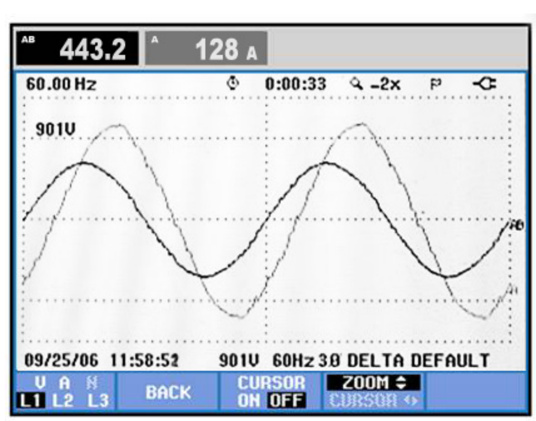
INTRODUCTION

Harmonics are a side effect of variable frequency drives and other non-linear systems such as computers, printers, fluorescent lights and power supplies. Most modern electronics change the frequency and voltage of the power used, and the current waveform can become quite complex. This waveform is composed of the fundamental frequency sinusoidal waveform with multiple harmonics (multiples of that frequency).

Harmonics have a negative effect both upstream and across the distribution. To mitigate these effects, several technologies can be employed. The most economic and effective of these is an Active Front End (AFE) drive. With an active front end, harmonics can be reduced to well below the IEEE 519 standards of 5% total demand distortion (TDD) and 3% voltage distortion at full load. This paper reviews the science of harmonics, the effect on equipment and power quality and the various options available for mitigation.



BEFORE: A study of this system provides the baseline of the current power quality.



AFTER: Once SPOC provides low harmonics drives for this system, it runs reliably & efficiently.

BENEFITS OF HARMONIC REDUCTION

Reducing harmonics is the right thing to do for your equipment, budget and standing with your electric utility. The cost of mitigation is recovered in better energy efficiency, lower maintenance costs and improved goodwill with the utility. Most utilities have IEEE 519 compliance requirements in their terms of service. When these limits are breached, utility meters cannot read data and the utility will likely demand the problem be remedied. There are benefits to the user as well, including:

- **Increased energy efficiency.** Harmonics reduce transformer efficiency. By minimizing harmonics, operators have fewer losses in the numerous transformers in their facility, saving money and extending their life. The power factor also is near unity in the absence (or near absence) of harmonics, reducing KVA loading and freeing up system capacity.
- **Less Heat.** High current resulting from harmonics can overheat transformers. This heat can significantly damage equipment or even cause burnout. By minimizing harmonics, operators prolong equipment life.
- **Proper transformer sizing.** One workaround for high heat situations has been to oversize transformers. The downsides to this approach are wasted energy and higher utility bills. By minimizing harmonics, operators can more properly size their equipment and increase energy efficiency.
- **Fewer breaker trips.** High quality power is much less likely to cause a spike or fault that trips a breaker. This keeps pumping equipment online and in production.
- **Low interference.** Low harmonics yield low interference with other systems nearby, including the power grid. Neighbors will not see interference in their electrical systems, including televisions, lamps and computers.

The more non-linear systems in use, the greater the harmonics. By adopting modern mitigation technology, operators can protect their investment in pumping equipment and their relationship with the power company and neighbors.

HARMONICS BACKGROUND

Electricity is delivered at a certain voltage and frequency. In the US, the voltage for residential use is 110v, while for heavy appliances like ovens and dryers it is 220v. The frequency is 60 Hz. In other parts of the world, the voltage is higher but frequency is lower (220v @ 50Hz).

Electrical frequency is a sinusoidal waveform. This smooth repetitive oscillation is disturbed when the frequency is modulated, creating harmonics. Harmonics are integer multiples of the fundamental frequency. For example, if the frequency is 50Hz, the harmonics are 100Hz, 150Hz, 200Hz and so on. The most disruptive harmonics are the 5th and 7th.

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Electricity is delivered in three phases, each 120° offset. In a perfect environment, these three phases are in perfect balance, each with exactly the same voltage. In reality, the voltage can vary significantly. This variance contributes to the complexity of mitigating harmonics.

Harmonics are propagated both to equipment and upstream into the power grid. The effect on the grid depends on the severity of the harmonic distortion and the size of the total energy pool.

Think of the power grid as a body of water and the harmonics as a pebble. If the harmonics are significant (big stone) and the body of water is small (pond) there will be a large effect when the stone is thrown into the water. The volume of non-linear systems (including drives) is rising much faster than the size of the electrical grid, increasing the harmonic effect. As solid state devices become increasingly more common, you can be assured that even if a utility does not have harmonic mitigation on its list of important concerns today, it will be concerned with harmonics soon.

PASSIVE 12- AND 18-PULSE DRIVES

While there are many 6-pulse drives on the grid today, for oilfield pumping equipment 12-pulse drives are now the minimum recommended specification. 12-pulse drives incorporate two rectifiers and require a special transformer to transform from alternating to direct current. The system relies on diodes or silicon control rectifiers (SCR) for the switching.

12-pulse drives are configured as a set of two 6-pulse rectifiers. Each rectifier is fed by a unique transformer with two sets of windings. One winding is typically connected in a star configuration while the other is delta. These sets are designed to offset each other, effectively cancelling or greatly reducing the 5th and 7th harmonics. In good conditions, this eliminates up to 75% of the harmonic current, making THD about 10%.

The 12-pulse approach works well when the voltage is balanced in all three phases, which is extremely rare. This design also depends on 100% load, where it is most effective. At other load levels, results vary. One operator found that they had over 50% harmonics from their lightly loaded 12-pulse drive.

18-pulse drives have a similar design to 12-pulse, now with three 6-pulse equivalents. Again, harmonic mitigation is most effective when voltage is balanced and load is 100%. An 18-pulse drive may achieve 90% THD reduction, taking THD to about 5% through near elimination of the 5th, 7th, 11th and 13th harmonics. It thus achieves better reduction than the 12-pulse, albeit at a higher cost. Because of the dependency in both cases on balanced voltage, performance is expected to degrade over time. As more drives and other non-linear systems are added to the grid, power quality will decline.

ACTIVE FRONT END DRIVES

As the name implies, AFE drives use an active approach to harmonic mitigation. Rather than depend on voltage balance, AFE drives sample the actual voltage and can then react appropriately. The drive can generate a more equal and opposite waveform to neutralize harmonic frequencies.

AFE drives do not depend on the power quality received but can instead compensate for whatever deficiencies are detected. If the power quality declines the drive will continue to perform at the same level.

An active harmonic system is comparable in concept to noise cancelling headsets. These devices use an active element (microphone) to detect background noise. They then generate an opposite waveform to cancel out the unwanted sounds.

In the AFE drive, harmonics are detected by transistors that then create an equal and opposite waveform to cancel the harmonics. These bi-directional power switching devices can regenerate energy and remove the need for braking resistors. Energy efficiency is improved if braking is regularly required.

ACTIVE HARMONIC FILTERS

Another form of active harmonic cancelling is available for retrofitting drives in place. While more expensive typically than AFE drives, active harmonic filters are an attractive option for installations that must be brought into compliance without changing out existing equipment.

An operator in Illinois investigated their power quality following complaints from a neighboring resident. The THD on the line was 7%, creating problems with the resident's television, telephone and touch-control lamps. To fix the problem, the operator had to take the unit offline for several hours and spend $30,000 for the retrofit. While expensive, this was a far better outcome than had the power utility levied a fine or worse yet, demanded the unit be taken off line.

ECONOMICS

Today, 12-pulse and 18-pulse drives may be good enough to pass regulations in some environments. Their design presents a risk, however, because performance is relative to the incoming power quality. If power quality declines, which is likely, the drives may no longer be in compliance. 12-pulse drives are less expensive than 18-pulse, which are about comparable in price to AFE drives.

AFE drives provide absolute reductions in harmonics rather than relative. Even if the power quality goes down, AFE drives will continue to deliver THD below regulated levels. AFE drive costs are relative to load size.

CONCLUSION

Harmonics are a growing issue in the oilfield. Several options are available to mitigate the effects. An AFE drives is the best solution for ease of installation, cost/performance and long-term effectiveness as load or well conditions change.

SPOC AUTOMATION builds world-class variable frequency drive (VFD) solutions for the oil and gas industry. SPOC engineers and packages artificial lift controls and automation technology that increases oil and gas production, lowers lifting costs and saves energy.

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