Referencing the following article: AADE-11-NTCE-7

The Price of Poor Power Quality

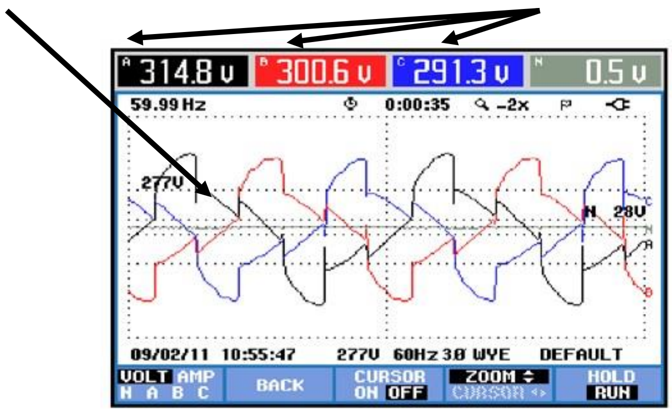
1.0. The importance of power quality

b) Voltage distortion due to the harmonic currents

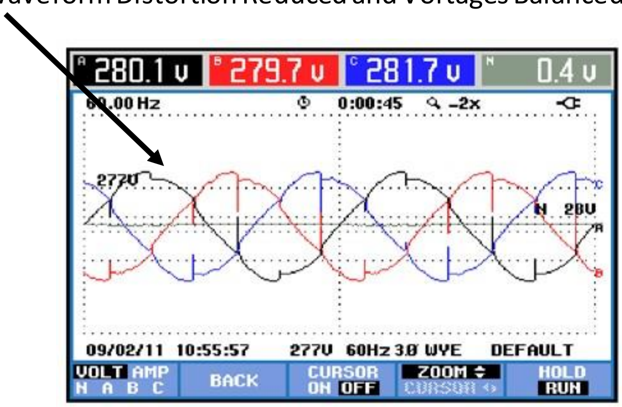
3.2. DC SCR drives "issues with "*line notching and occasionally voltage spikes are the unwelcome result*"

4.0. Line notching 'Line notching' is usually associated with phase controlled semi-conductors Phase

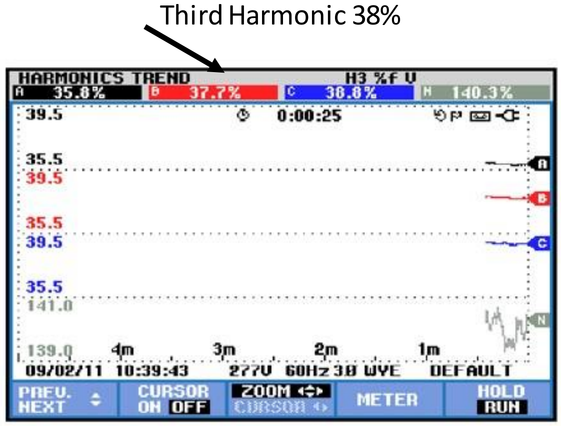
Voltage Notching Causing Waveform Distortion and Voltage Imbalance



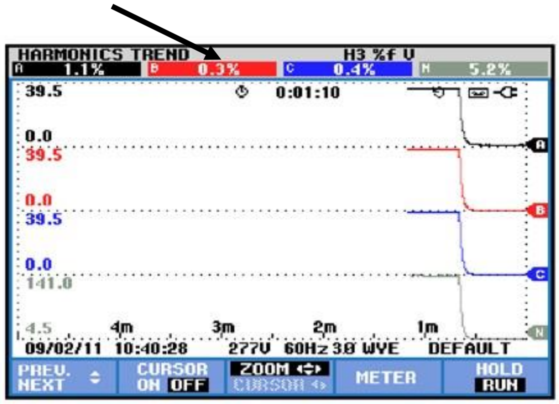
Phase Voltage Waveform Distortion Reduced and Voltages Balanced with Phaseback VSGR



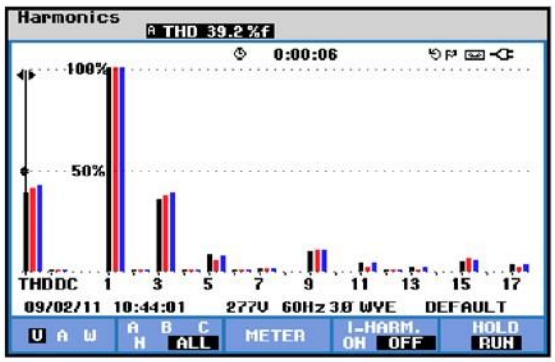
Third Harmonic 38%



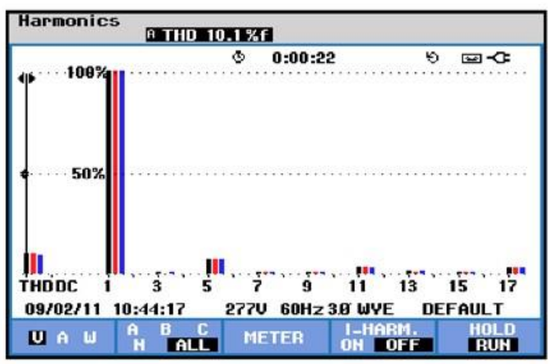
Third Harmonic Reduced 98% with Phaseback VSGR



Total Harmonic Distortion



Total Harmonic Distortion Reduced 75% with Phaseback VSGR



3.1.2. Passive Wide Spectrum Filters, sometimes referred to as "Amp Trap" filters must conduct all the harmonic current removed from the power system to ground as shown in figure 16 minus figure 17 in filter figure 13. Filters of this general design have a high capacitor failure due to the combined currents of all the frequencies they must conduct and the voltage spikes present in the ungrounded and unregulated power systems. The above solution is from a 750 kVA power transformer running 20 degrees hotter than design due to supplying the power to operate the 200 hp SCR drive and the 350 kW Amp Trap filter. When the VSGR was added it drew less than 1 amp of current, was less than 1/50th the size and operates cool without any component failure.

The 750 kVA power transformer is now operating with in its operational design temperature. The production equipment now operates reliably and quietly without the previous drive or motor noise.

Amp Trap and other types of filters that remove harmonic currents provide a low impedance path for harmonic curren t.

They do not improve the overall efficiency of the operation as the unwanted noise is still generated, the drives still draw all of their power from the source (generator of power transformer) so they do not actually reduce the total current loading referred in the article.

3.1.3. Active filter solutions: figures 18 and 20 show and imply a grounded WYE generator or transformer, typically the generators in this market are ungrounded WYE and the transformer secondaries are ungrounded DELTA.

With grounded WYE power transformers there are high harmonic currents as the WYE connection does not mitigate these currents, they simply conduct into and out of the transformer. When using a DELTA power transformer many of the harmonics cause circulating current in the low impedance secondary which reduces these harmonic at the square of the frequency. The 3rd harmonic is reduced by a factor of 9, the 5th harmonics is reduced at a factor of 25, and the seventh harmonic is reduced at a factor of 49. This clearly shows that the higher the harmonic the more the harmonics are filtered.

4.1.1. Line reactors

Line reactors, like any other inductor, are designed to resist a change in current to help smooth the current. To provide this resistance to current flow, called inductive reactance, it must cause a voltage drop across the reactor. When there is a voltage drop and increased reactance the VFD is limited in the voltage and current it receives from the source. This will affect the performance and potentially operation of the motor. This is another type of inefficiency added to the system. Many applications have over voltage faults as a motor powered from a VFD is decelerating due to the voltage drop across the line reactor. During deceleration the source is the motor and the incoming line and/or the breaking resistor is the load.

When adding a Phaseback DVS (Drive Voltage Stabilizer) to the drive output terminals the voltage spikes are mitigated (reduced) and the harmonics are reduced typically by 50 to 85% cleaning up the power without limiting the power to the motor or adding a power reducing device to the circuit. ***5.0. Voltage spikes***

As the terms suggests, 'voltage spikes' are exactly that; spikes of overvoltage superimposed on the supply voltage.

5.1. Attenuation of voltage spikes

It is important to understand the causes of voltage spikes and harmonics as well as their interactions to solve the damage and inefficiency issues associated to ungrounded power systems. The capacitance in the system, phase to ground, is NOT parasitic it is beneficial. When the phase voltages are balanced the capacitive charge energy is balanced. When this charge becomes unbalanced the phase voltages become unbalanced, as the harmonics increase the phase voltages become unbalanced and as current harmonics increase they cause an increase in voltage harmonics. There are many causes of voltage waveform distortion and instability but it the voltage that is common among all power system loads. Each load draws current based on its design and impedance but they all share the same voltage. Current harmonics and unbalanced loads from all causes is only a problem when they interfere with the operation of other equipment.

Balancing and stabilizing the voltages with respect to ground reduces the voltage waveform distortion, voltage harmonics and can actually reduce the likelihood and severity of an arc-flash hazard increasing the safety of the power system. Simply adding a Parallel connected Phaseback VSGR (Voltage Stabilizing Ground Reference) to the secondary circuit of each power transformer removes the negative effects: a noisy ungrounded power system as well as removes the damage and downtime they cause. ***6.0. Common mode voltages***

The voltage spikes shown in figure 35 look similar to the switching transients caused by the IGBT outputs turning ON and OFF. These voltage spikes can be removed with the addition of a Phaseback DVS.

"Note that common mode currents in ii) can often find their return paths through the motor bearings. Micro-arcs in the bearings created by make-and-break operation during rotation while carrying currents create pitting and can accelerate decomposition of surface smoothness creating a host of problems."

The well documented cause of shaft current is the 7^{th} harmonic causing 6^{th} harmonic voltage drop across the motor rotor shaft. This voltage drop can exceed 60 times the normal value and it takes every current path available to it but the bulk of the current travels from the shaft to the motor end bells and frame through the bearings. Reducing the 7^{th} harmonic, insulating the bearing from the end bell or adding a brush to discharge this voltage has provided positive results in reducing bearing failure in electric motors. The addition of a Phaseback DVS reduces all harmonics including the 7^{th}.

There are some drive basics that need to be understood to solve these types of electrical noise and the negative effects:

1) A VFD front end rectifies (converts) AC to DC
2) The storage section stores electricity in a group of large capacitors
3) The output section converts the DC into a variable frequency – variable voltage set of pulses
4) As the output is sending current to the motor it instantly requires current from the capacitors
5) The outputs are sending current pulses to the motor drawing current pulses from the capacitors
6) The current travels at approximately the speed of light to the motor and from the capacitors
7) The capacitors require instantaneous current pulses from the incoming rectifier section
8) The fast high current demand from the rectifier section causes the incoming voltage to dip
9) The voltage dips will occur at the drive switching frequency
10) The voltage dips cause voltage waveform distortion
11) When the voltage waveform distortion causes problems it must be corrected
12) Every load draws current based on the system dynamics and the impedance of the load
13) All loads share the voltage and when it is distorted it affects the operation of controls and drives

This is somewhat simplified however it gives a basic uncomplicated understanding of what is going on, what is causing it and what to do to correct it for reliable operation.

The voltage is constant (shared) in a parallel circuit but it is the current which changes in each path based on its impedance.

5.1. Typical common mode problem

Systems with the same power systems, drives and loads will have the same power issues. Many industries which have converted from across the line single speed motor control to adjustable or variable speed control share the same issues. When the percentage of non-linear load causes a high total harmonic distortion at the point of common coupling there will be unreliable operation and prematurely damaged equipment.

When solving all of these power issues by adding a Phaseback VSGR there is an additional benefit beyond reducing harmonics and voltage spikes as the equipment operates cooler and with lower voltage stress it operates longer with higher efficiency. With only one Phaseback VSGR per power transformer or generator there is a 1 to 2 year payback due to increased energy savings.

Respectfully submitted,

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