Proper Grounding for VFD and Motor Systems

Aquatic Animal Life Support Operators Symposium

May 3, 2010

Topics

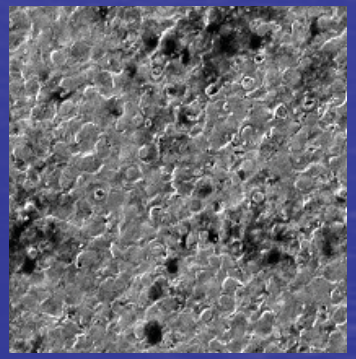
- Shaft Currents and their negative effects
- Drive/System Grounding: Do's and Don'ts
- Motor bearing and ground currents:
  - effects and problems that result
  - Shaft Current Prevention

Shaft currents can lead to motor failure

- Currents exit the system via the shaft bearings
- Bearings can erode and break down as a result
- Service life of motor reduced
  - 90% reduction in life and higher
  - Higher maintenance
  - Critical processes affected

Types of failure observed

- Pitting of bearings
  - Results at point of current discharge across a bearing on the bearing race
- Frosting
  - This is the result of continued pitting from the bearing discharge
  - Typically observed when a process motor speed widely varies during operation



Types of failure observed

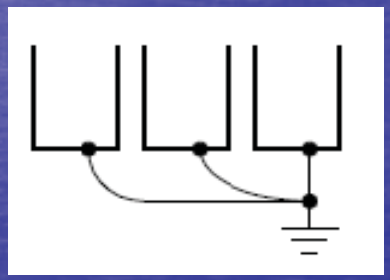
- **Fluting**
  - These are patterned ridges in the bearing race
  - More commonly observed in systems that have high constant speeds

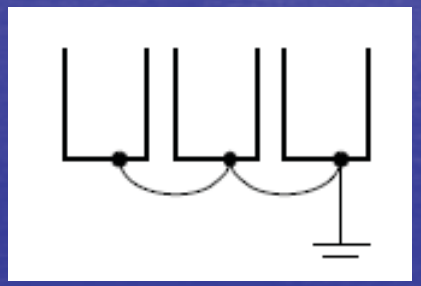
Sources of Shaft Unwanted Currents

- Poor equipment grounding practices
- VSD (Variable speed drive) introduces induced currents not seen with direct across-the-line motor installations.

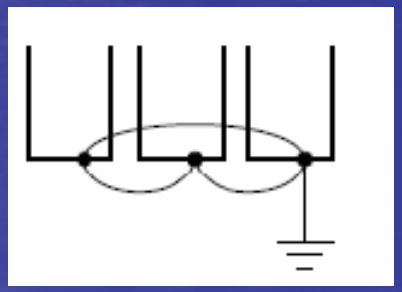
Grounding practices

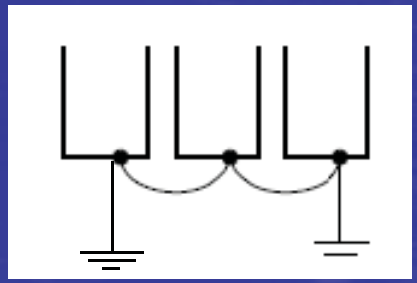
- Apply grounding for VSD and Motors as illustrated.
  - Correct





  - Incorrect





Other Grounding Considerations

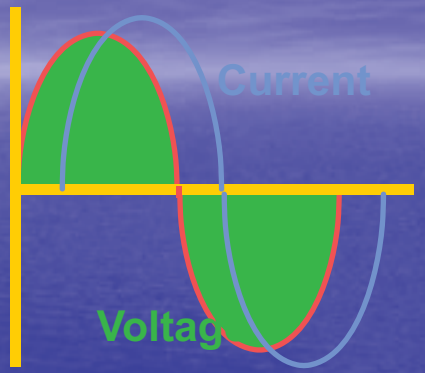
- Avoid Ground Loops
- Do not ground VFD/Motor at same common as welding equipment
- Avoid grounding near transmission towers
- Check grounding lugs in panels
  - Paint / Corrosion can cause barriers to grounding
  - Star washers, or ground screw directly welded to panel.
  - Ensure true path to earth

VFDs are being applied to motors with increasing frequency

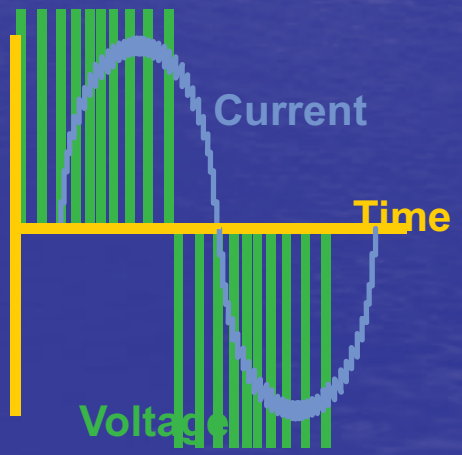
- VFDs save energy, provide smoother operation, and overall improve applications involving motor driven processes.
- Cost competitive with AC contactors and overloads.
- VFDs introduce new problems due to the pulse width modulation (PWM) method of producing sine waves

VFD Pulse width modulation

- What an across-the-line motor sees

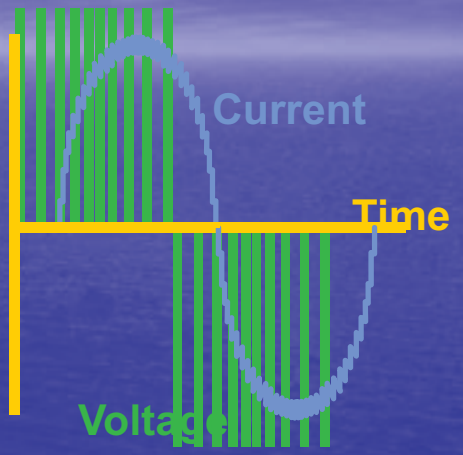


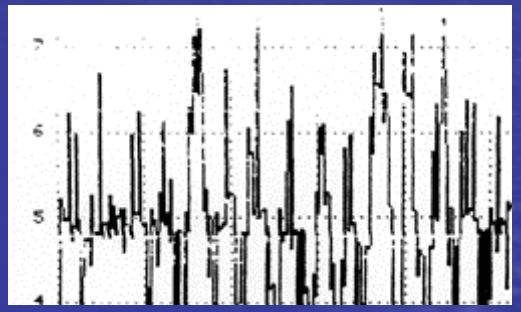
- What a VFD Driven motor sees
  - "Bursts" or "Pulses" at 650+V
  - 2000-16000 times per second/per phase!



VFD Pulse width modulation

- The instantaneous sum of 3 pulse width signals cannot be 0.
- + and - DC voltages are the result, which is also known as Common Mode voltage.





VFD Pulse width modulation

- Potential for the pulses to periodically exceed the dielectric strength of the air gap between stator windings and rotor laminates
- Resulting unwanted voltage surges migrate from rotor to shaft
  - Have been observed to be as high as 70Volts in some systems
  - Looking for a ground path for discharge.

Failure progression from Rotor to Bearings

- Bearings sit in a film of lubricating oil
- The stray voltages find "opportunities" to overcome the dielectric strength of the film.
  - Relatively large discharge in a small area causes damage.
  - Eventual breakdown of lubricating oil will further aggravate situations.

Bearing discharge to failed motor progression

- Pitting as discharge occurs
- Frosting as progressive pitting continues
- Fluting in many cases
- Added friction in the bearing raceway
  - Heat and mechanical wear on bearings
  - Failure of bearings / process

Solutions to alleviate bearing discharge

- **Insulated bearings:** Sounds like a simple solution, but…
  - Expense makes this impractical for smaller motors.
  - This only transfers the discharge point away from the motor bearings
- Possible new discharge areas
  - Pump
  - Any gauge or tach in the system

Solutions to alleviate bearing discharge

- **Ceramic Bearings**: better dielectric strength than insulated bearings, but:
  - Expensive solution
  - Difficult retrofit, as mechanical properties of ceramics will typically require larger ceramic bearings than metallic.
  - Still transferring shaft ground currents elsewhere rather than eliminating them.

Solutions to alleviate bearing discharge

- **Grounding Brush**: Metallic conducting brush rides on rotor. Conductive path for shaft currents.
  - Placement is important. Usually on load end of motor shaft.
  - Implemented along with insulated bearings, this can be a good solution
  - Downside:
    - Brush wear, so periodic maintenance
    - Brush could collect contaminants that could cause mechanical wear at shaft.

Solutions to alleviate bearing discharge

- **Conducting grease:** Metallic particles in grease provide low impedance outlets for shaft currents.
  - Abrasive compounds: Introduce mechanical wear on bearings
- **Faraday (electrostatic) shield**: Capacitive barrier between stator and rotor.
  - Expensive solution
  - Potential for path from stator winding through frame and back up through bearings to shaft.
  - Largely used by chip/board makers where the shaft currents can contaminate the board.

Solutions to alleviate bearing discharge

- **Shaft Grounding Rings**: Rings that slip on the shaft and contain conducting microfibers.
  - Similar principle to grounding brushes except the fibers "fixed" in a composite.
  - Many more microfibers that in brushes
  - Wear is minimal

Solutions to alleviate bearing discharge

- Drive design modification to mitigate sources from the PWM.
  - Expenive solution
  - Technology has not been fully developed
- Output filters for dV/dt
  - Will provide filtering for the output common noise voltage
  - Helpful, but mitigates rather than neutralize the problem.

Summary

- The use of VFDs, while having many advantages, can also produce additional problems in systems.
- Proper grounding can prevent problems of stray shaft currents.
- Addition of grounding devices on the shaft or bearing conditioning can neutralize these problems.