



# **VARIABLE FREQUENCY DRIVE CABLE**

*Daniel G. Mainstruck  
Sr Applications Engineer  
Willimantic, Connecticut*

# Agenda

---

- **Introduction - Terminology**
- **What does a VFD do ?**
- **Reported Issues affecting Cable Selection**
- **Findings of the IEEE Pulp & paper Bentley Link study**
- **Conclusions**

## AC Drive Terminology - Buzz Words

---

- **VFD** - Variable Frequency Drive
- **VSD** - Variable Speed Drive
- **ASD** - Adjustable Speed Drive
- **PWM** - Pulse Width Modulation
- **IGBT** - Insulated Gate Bipolar Transistor
- **GTO** - Gate Turn Off
- **BJT** - Bipolar Junction Transistor

## WHAT DOES A VFD DO ?

---

- Converts or Rectifies the Incoming AC 60 Hz Voltage to DC
- Re-converts or Inverts this DC voltage back into an AC output but with a variable or adjustable frequency

## Variable Frequency Drives

---

- This AC Output (to the Motor) is through Pulse Width Modulation in the VFD's Inverter Section using solid state switching devices such as Insulated Gate Bipolar Transistors ( IGBTs ), Gate Turn Offs ( GTOs ), or Bipolar Junction Transistors ( BJT )

## Variable Frequency Drives

---

- These solid state devices enable the VFD to produce an output with PWM or a series of DC voltage pulses of constant amplitude but with varying pulse width
- Newer VFD's with IGBT's produce DC pulses with very fast voltage rise times providing better, more precise motor speed control

## Variable Frequency Drives

---

- Resulting in precise control of motor speeds, high motor efficiency, and the motor retains its torque when the VFD is adjusted to operate at very low speeds.

## New AC Drive Technology

---

- Replaces the older DC Drive systems
- Reduces the size and increases efficiency of VFD's while improving control of motor's speed and torque
- Improvements are of an exponential magnitude, including accelerated switching speeds.

## Issues Affecting Cable Selection

---

- Electromagnetic Interference ( EMI )  
that can lead to cross-talk
- Ground Currents
- Common Mode Currents
- Reflected Waves

## ELECTROMAGNETIC INTERFERENCE

---

- Induced Current/Voltage ( Cross-talk )  
on adjacent cables
- Potential disruption of Equipment  
and/or Processes
- Potential Safety Hazards
  - De-energized equipment can be activated  
by electromagnetic/electrostatic coupling  
while maintenance is being performed on  
it.

## HIGH GROUND CURRENTS

---

- Currents are induced on the Protective Earthing (PE) Ground Bus
- Potential Disruption of Control Circuits when the Drive Power and Control Circuits share a common system

## COMMON MODE CURRENTS

---

- Caused by Currents introduced by unbalance between the drive and the power cable
- Potential for Stray Currents returning to the Inverter via Motor Bearings causing bearing failure

## REFLECTED WAVE PROBLEM

---

- Known as “Transmission Line Effect” or “Standing Wave”
  - Due to an Impedance mismatch between cable and connection to motor terminal
- Cable potentially sees a Pulse Voltage up to 195 % of RMS Peak



Cables Studied in IEEE Pulp & Paper 1996

Bentley & Link Paper

- **Tray Cable - 3 Grounds ( NEC Type TC )**
- **GSIA MC - 3 Grounds ( NEC Type MC )**
- **AIA MC - 3 Grounds ( NEC Type MC )**
- **GSIA MC - 3 Grounds - Copper Tape Shield ( NEC TYPE MC )**
- **IEC - S - No Ground - Tape & Wire Shield ( IEC-Symmetrical )**
- **IEC - A - 1 Ground - Tape & Wire Shield ( IEC-Asymmetrical )**
- **CCW MC - 1 Ground ( NEC Type MC )**
- **CCW MC - 3 Grounds ( NEC Type MC )**

## CABLE DESIGN SOLUTIONS

---

- Recommended Cable Construction - CCW  
Continuous Corrugated Welded Armor  
General Cable® Philsheath®
- Compressed Concentric Copper Conductor
- High Dielectric Strength Thermoset Cross-Linked  
Polyethylene ( XLPE ) Insulation  
Wall Thickness per XHHW-2 or ICEA 2000 Volt
- Three Insulated Conductors cabled with three  
Symmetric Bare Copper Ground wires or  
( Bonding Conductors ) Fillers ( As Necessary )  
and a Binder tape
- CCW Continuous Welded & Corrugated Armor
- Overall Polyvinyl Chloride ( PVC ) Jacket

## CABLE DESIGN SOLUTIONS

---

- Completely Self contained Cable/Conduit System
- Impervious to Moisture, Gas and Liquids
- Aluminum Sheath provides an excellent shield for High Frequencies and retains good shielding capability as the cable ages.
- PVC Jacket prevents metallic sheath from coming in contact with ground in the route to the motor
- Excellent Flame, Crush, and Impact resistant along with resistance to Mechanical Abuse
- Flexible for Cable pulls
- Hazardous Locations ( UL Type MC-HL )

# CABLE DESIGN SOLUTIONS

---

- Reduced EMI for frequencies associated with PWM Drives
- Provides a symmetric cable ground system which will generate minimal Ground Currents and reduce Common Mode Currents
- Provides a Low Impedance Path to ground which reduces the risk of motor bearing failure due to stray currents

## CONCLUSIONS

---

- Cables are the nearly invisible infrastructure, generally taken for granted
- Cable Design and Engineering are not as simple and straightforward as one might assume
- Don't assume that the same old cable will work in a similar application unless you know for sure

## CONCLUSIONS

---

- Don't Overlook or Underestimate the most basic connecting link in the Electrical system just because all cable looks the same
- So, Why should you worry about redesigning Power cables for use with AC Drives ?
- You Shouldn't because We Do !!!!