Installation Considerations for VFDs
Identifying Your Power System

Delta / Wye with grounded Wye neutral (Recommended)

- **Reasons for use:**
  - Delta / Wye with Grounded Wye Neutral is the most common type of distribution system
  - Controlled path for common mode currents
  - Consistent line to ground voltage reference which minimizes insulation stress
  - Better accommodation for system surge protection schemes
- Rockwell strongly recommends the use of grounded neutral Wye systems for Variable Frequency Drives and DC Drives
Identifying Your Power System

Ungrounded Delta/Wye and Delta/Delta (Not Recommended)

- **Reasons for use:**
  - Offer a measure of protection against high current ground faults. You can still run while a ground fault condition is present.

- **Warnings:**
  - Allows transient over-voltages to form during ground faults. Ground faults on the secondary can cause primary voltage to ground on the secondary side. I.E. 13.8Kv to 480V transformer can have 13.8kv to ground on the secondary in the event of a ground fault.
  - No Common Mode Current path, high probability of issues with other instrumentation.
  - A higher line-to-ground voltage (1.732 x) than in a neutral-grounded system,
  - MOV’s and Common Mode Capacitors in electronic equipment referenced to ground must be disconnected. Removing the MOV’s to ground the system loses UL and CE certifications.
Identifying Your Power System

Delta / Delta with Grounded Leg or Four-Wire Connected Secondary Delta (Not Recommended)

 Reasons for Use:
• A configuration providing voltage re-balancing with no phase shift between input and output.
• Ability to supply dual-voltage service for lighting and power loads. Allows for a tapping of a leg for these voltages

Warnings:
• Requires the identification of the grounded phase throughout the system to avoid connecting current measurement devices I.E. Meters, fuses, instruments, and relays in the grounded phase
• A higher line-to-ground voltage on two phases (1.732 x) than in a neutral-grounded system
How do you know which power system you have?

- Look at the supply transformer nameplate
- Check for a power one line of the facility
- Measure voltage phase to ground
  - Ungrounded systems will most likely not have consistent voltage readings to ground for each phase
- If in doubt supply a separately derived source by adding a Delta/Wye grounded neutral secondary transformer for the drive system
Identifying Your Power System

Transformer sizing guidelines

- For harmonic considerations the total drive (non-linear) loading should not exceed 60% of the transformer KVA rating.
- If your transformer size exceeds the following guidelines, add a line reactor:
  - Transformer KVA rating should not exceed 20:1 ratio above the individual drive KVA rating for drives with DC link choke or percent source impedance relative to the drive impedance is < 0.5%
  - Transformer KVA rating should not exceed 10:1 ratio above the individual drive KVA rating for drives without DC link choke or percent source impedance relative to the drive impedance is < 0.25%
  - Refer to Publication DRIVES-IN001 under AC Line Impedance section.
Identifying Your Power System

EXAMPLE

The drive is rated 1 Hp, 480V, 2.7A input. The supply transformer is rated 50,000 VA (50 kVA), 5% impedance.

\[ Z_{\text{drive}} = \frac{V_{\text{line-line}}}{\sqrt{3} \cdot I_{\text{input-rating}}} = \frac{480\text{V}}{\sqrt{3} \cdot 2.7} = 102.6 \text{ Ohms} \]

\[ Z_{\text{xfmr}} = \frac{(V_{\text{line-line}})^2}{\text{VA}} \times \% \text{ Impedance} = \frac{480^2}{50,000} \times 0.05 = 0.2304 \text{ Ohms} \]

Note that the percent (%) impedance has to be in per unit (5% becomes 0.05) for the formula.

\[ \frac{Z_{\text{xfmr}}}{Z_{\text{drive}}} = \frac{0.2304}{102.6} = 0.00224 = 0.22\% \]

0.22% is less than 0.5%. Therefore, this transformer is too big for the drive. Consider adding a line reactor.
What a VFD does and what the input/output voltage and current looks like

3.75 MVA
460 V
5.75%

1) Ref A: 100 A, 2 ms
2) Ref B: 10 V, 2 ms
Creation of common mode current

Switching Pattern (PWM) of Output IGBT

Common Mode Voltage pattern

$V_{ng}$

$I_{lg}$

4 kHz
Common Mode Current Path and Effect on Electronic Equipment

Common Mode Noise Current Path causing ground EMI Interference

Potential #1: Interface Electronics
- 0-10V, communication
- 4-20 mA, sensor interface, etc.

Potential #2: Logic

Potential #3: Motor Frame
- Motor
- Tach

Potential #4: True Earth Ground (TE)
Installation Considerations

Power Jumpers for the PowerFlex® 7xx Class drives

Power jumper circuit locations
Cable Types

• Input Cables
  – No Special Considerations

• Output Cables
  – Length
    • Cable Charging Current
    • Reflected Wave
    • Voltage Drop
  – Type
    • Individual conductor
    • Bundled cable
      – Shielded
      – Unshielded
Cable Charging Current
Output Cable Length Considerations

• Cable Charging Current
  – At every switch of the IGBT the capacitance of the cable must be charged
    • For smaller motors (<2HP) the cable charging current can exceed the motor/drive current rating
    • I.E. with a 5ma per foot charging current on a 300 ft. run the charging current will be 1.5 amps which is the equivalent current of a 1 HP motor at 460VAC.
  – Mitigation Techniques
    • Use a larger drive to supply the cable charging current
    • Common Mode Choke around the motor leads
    • Output Line Reactor
    • Move the drive closer to the motor
Output Cable Length Considerations

- Reflected Wave
  - Voltage magnitude of drive pulse
  - Motor and cable surge impedance mismatch
  - Rapid rise time of drive pulse due to type of semiconductor switch in the drive
  - Long cable length
Typical Failure, Very Subtle and Hidden in windings
Output Cable Types

• Reflected Wave, what can we do about it?
  – Keep motor lead lengths as short as possible
  – Specify and buy inverter duty insulated motors (with NEMA motor standard MG1 part 31 1992)
  – Install a motor “protection” device where needed
  – Reflected wave reduction method at the drive
### Table 46 - PowerFlex 753 and 755 Wall Mount Drives, 400V Shielded/Unshielded Cable – Meters (Feet) (continued)

<table>
<thead>
<tr>
<th>Drive Rating</th>
<th>No Solution</th>
<th>Reactor Only</th>
<th>Reactor and Damping Resistor or 1321-RWR</th>
<th>Available Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame kW kHz</td>
<td>1000V 1200V</td>
<td>1488V 1600V</td>
<td>1000V 1200V 1488V 1600V 1000V 1200V</td>
<td></td>
</tr>
<tr>
<td>15 2 7.6 (25)</td>
<td>137.2 (450)</td>
<td>365.8 (1200)</td>
<td>91.4 (300) 91.4 (300) 365.8 (1200)</td>
<td>TA1</td>
</tr>
<tr>
<td>4 7.6 (25)</td>
<td>91.4 (300) 152.4 (500) 213.4 (700)</td>
<td>18.3 (60) 18.3 (60) 365.8 (1200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 18.5 2 7.6 (25)</td>
<td>137.2 (450)</td>
<td>365.8 (1200)</td>
<td>91.4 (300) 91.4 (300) 365.8 (1200)</td>
<td>TA2</td>
</tr>
<tr>
<td>4 7.6 (25)</td>
<td>91.4 (300) 152.4 (500) 213.4 (700)</td>
<td>18.3 (60) 18.3 (60) 365.8 (1200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 2 7.6 (25)</td>
<td>137.2 (450)</td>
<td>365.8 (1200)</td>
<td>91.4 (300) 91.4 (300) 365.8 (1200)</td>
<td>TA3</td>
</tr>
<tr>
<td>4 7.6 (25)</td>
<td>91.4 (300) 152.4 (500) 213.4 (700)</td>
<td>18.3 (60) 18.3 (60) 365.8 (1200)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*From Appendix A of Wiring and Grounding Guidelines Publication DRIVES-IN001*
Classify Categories of motor insulation at 0.1 us rise time:

- **1,000 Vpk Category**: Motors without phase & slot insulation
- **1,200 Vpk Category**: Motors with additional phase insulation
- **1,488 Vpk Category**: Preferred Choice for 480 V IGBT Drives
- **NEMA MG1 Part 31.40.4.2, 1998**: “Insulation can withstand voltage spikes of up to 3.1 times motor rated voltage” which specifies for 480 volt application 1488 VPK.
- **1,600 Vpk Category**: Motors manufactured for Rockwell for 480 volt applications
- **1,850 Vpk Category**: Motors manufactured for Rockwell for 600 volt applications
- **2000 Vpk category**: Motors manufactured for 690 volt applications
Cable voltage drop is another consideration in cable length as the voltage drops the current increases at the motor

- Resistive voltage drop
  - Voltage Drop = Rated Current * Cable Resistance * Motor Power Factor
- Reactive voltage drop is another consideration
  - $2\pi \times \text{Fundamental Frequency} \times \text{Cable Inductance}$
Cable Types

• Individual Conductors
  – XLPE type insulation is recommended
  – THHN is not recommended
    • THHN is susceptible to moisture
    • Outer nylon cover can crack and reduce corona inception voltage rating
Common Mode Currents in Conduit

CONDUIT PROVIDES GOOD WIRING NOISE CONTROL BUT ACCIDENTAL CONDUIT CONTACT TO GROUND MAY ALLOW $I_{lg}$ NOISE PATH BACK TO GROUND
Cable Type

• Bundled (No Shield)
  – Benefits
    • Ease of installation compared to individual conductors
    • Lower cable charging current with XLPE insulation compared to shielded cable
  – Disadvantages
    • Radiated emissions higher than shielded cable
    • Geometry of the cable can effect the radiated emissions
Cable Type

• Bundled (Shielded)
  – Benefits
    • Ease of installation compared to individual conductors
    • Lower radiated emissions
    • Common mode current directed back to the source
  – Disadvantages
    • Higher cable charging current
Additional Containment of Common Mode Current Paths - Better

Shielded output cable/armor with PVC jacket PROVIDES BETTER WIRING & NOISE CONTROL WITH NO ACCIDENTAL ARMOR CONTACT TO GROUND BUT IF NOT USED ON INPUT MAY ALLOW Ilg NOISE PATH BACK TO GROUND
Agenda

- Identifying Your Power System
- Installation Considerations
- Panel Installation Practices
Containing Common Mode Current Paths to Prevent Problems Start with Good Panel Layout

For PLC grounding recommendation refer to Publication 1770-4.1
Panel Layout is Important

Better Panel Layout
Other things to consider

- Follow proper wire spacing guidelines
- If control and power wires must cross, do this at a 90 degree angle
- Surge suppress any large inductive loads (i.e., mechanical brakes, contactors, etc.)
- Do not use a painted surface for a grounding point (galvanized backplane suggested).
- When routing signal wires, route the feed and return together or use twisted pair wire.
- Avoid nicking wire insulation when going through flexible conduit
Questions