CT337

Installation Considerations When Applying Variable Frequency Drives
Today You Will Learn:

• How to correctly size your VFD

• How to properly install to minimize problems.

• How to mitigate Reflective Wave voltage spikes

• How to dampen the effects of Common Mode Current
Collect the Motor Data

- Select Your VFD Based on Motor Nameplate Amps
- Record:
  - Volts
  - Amps
  - RPM
  - Hz
Read the Nameplate

- Confirm the Input Voltage
- Confirm the Output Current
  - Current needs to be greater than or equal to the motor nameplate value
  - **Always Select the VFD Based on Motor Nameplate Current!**
    - Horsepower is a nominal rating

![Motor Nameplate Image](image-url)
Plan the Installation

Transient Common Mode Current on Armor

A

B

Plastic Logic Controller (PLC) or Electronics

A

B

ASD Output Conduit / Armor bond to cabinet

ASD Input Conduit / Armor Bond to cabinet

PLC or Electronics

Optional PE to Building Structure

PE Copper Bus
Pay Attention to Clearances

Mounting Option A
No clearance required between drives.

Mounting Option B
Pay Attention to Clearances?
Heat Is Your Enemy!

- Just because it fits in the box, doesn’t make the enclosure the correct size!

Think of it as a 100 watt light bulb!

Don’t bake your VFD in an Easy Bake Oven!
Heat Is Your Enemy!

- Heat rises, give it a path to flow.

Install the unit vertically to allow airflow through the heat-sink cooling fins.

Don’t block the cooling fan!

<table>
<thead>
<tr>
<th>Ambient Operating Temperatures</th>
<th>Table 1.B Enclosure and Clearance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature</td>
<td>Enclosure Rating</td>
</tr>
<tr>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>-10°C (14°F)</td>
<td>40°C (104°F) IP 20/Open Type IP 30/NEMA 1/UL Type 1(1)</td>
</tr>
<tr>
<td>50°C (122°F)</td>
<td>IP 20/Open Type</td>
</tr>
</tbody>
</table>

(1) Rating requires installation of the PowerFlex 4 IP 30/NEMA 1/UL Type 1 option kit.
Pay Attention to Clearances?
Power to Power Motor to Motor

Table 1.F Power Terminal Block Specifications

<table>
<thead>
<tr>
<th>Frame</th>
<th>Maximum Wire Size (1)</th>
<th>Minimum Wire Size (1)</th>
<th>Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.3 mm² (12 AWG)</td>
<td>0.8 mm² (18 AWG)</td>
<td>1.7-2.2 N·m (16-19 lb·in.)</td>
</tr>
<tr>
<td>B</td>
<td>5.3 mm² (10 AWG)</td>
<td>1.3 mm² (16 AWG)</td>
<td></td>
</tr>
</tbody>
</table>

(1) Maximum/minimum sizes that the terminal block will accept - these are not recommendations.
Pay Attention to the Control Voltage

Don’t let the Magic Smoke out!
Proper Grounding is a Must!

Typical Grounding
Is Your Input Power Grounded or Floating?

- Ungrounded Power Systems may require the *removal* of the Input MOV jumper
AC Drive and Motor Installation Practices

A little protection and good technique go a long way to insure a good drive installation.

Tell me again why I'm using drives?

Line Transients

Harmonics

Grounding & Bonding

Common Mode & Capacitive Coupling

Reflected Wave
Why Should I use a DRIVE?

• To improve process control though speed and torque control

• To improve system efficiencies

• To extend life of equipment by reducing mechanical stress

• Reduce power demand – Save Energy
Why Develop the Variable Frequency Drive?

- **The Promise:**
  - To be able to electronically vary the speed and torque of any constant speed AC Motor.

  - **Torque** is proportional to applied **Voltage**.
  - **Speed** is proportional to applied **Frequency**.
A Little Motor Fodder?

- Most Common Enclosure is “TEFC”
  - Totally Enclosed, Fan Cooled
  - Fan attached to motor shaft rotates at same speed as motor shaft
  - Blows air over outside of motor frame to dissipate internal heat
  - Designed to provide sufficient cooling on line power to keep motor from overheating
  - Remember: **HEAT KILLS**
What Do We Know About Fans?

- Governed by the “Laws of Affinity”
  - It’s a LAW, which means it applies under all circumstances
    - Law # 1
      - The volume of air moved by a fan is directly proportional to its speed.
        - Faster = More Air
        - Slower = Less Air
  
- If That Fan is Being Used to Cool an AC Motor, and the AC Motor is Operating at Less than Nameplate Speed, the Fan is Moving Less Air and Providing Less Cooling!
A Little History Lesson About AC Motors

- Late 1980’s/Early 1990’s
  - No general supplier of “Inverter Rated” motors
  - **VFDs applied to motors caused failures due to overheating!**
  - A few niche suppliers modified general purpose motors to keep them cool when operating at reduced speeds.
    - De-rated Higher Horsepower Motors
    - Larger metal mass = better heat transfer
    - Added Constant Speed Blowers
    - Constant cooling regardless of motor speed
  - Addressed Only the Motor Thermal Issues
  - IGBT Start to be Used By VFD Manufacturers
    - Motor Service Centers Started Seeing Increased Volume of Motor Winding Failures
What is an IGBT?

- **Insulated Gate Bipolar Transistor**
  - Hybrid cross between a MosFET and a Darlington Power Transistor

- An **Insulated Gated Bipolar Transistor** is a power switching device capable of interfacing with low signal level logic control.

![Conventional model of IGBT](image-url)
IGBT Advantages in AC drives

- Higher Switching (Carrier) Frequencies than Bipolar Transistors
  - Lower Motor Noise
    - Higher Switching Frequency
    - 4kHz Typical
  - Lower Motor Heating
    - Motor Friendly Current Waveform Due to Higher Switching Frequency producing Less Waveform Ripple
  - Better Field Oriented Control
    - Higher Switching Frequency Allowing for Faster Response Time
IGBT vs. Bipolar Transistor Current

7.5HP MOTOR

1336 @ 60HZ NO LOAD SWITCHING FREQUENCY 1.26KHZ

1336 PLUS @ 60HZ NO LOAD SWITCHING FREQUENCY 8KHZ
IGBT Advantages in AC drives

• Drive Size Reduction
  – High Input Impedance – IGBT
  – Voltage “Gated (Switch on/off)” Device
    – Reduces Base Driver Power Consumption
    – Reduces Base Driver Board Size

5Hp PowerFlex40
IGBT

5Hp 1333 Darlington Pwr

4” x 8.4” x 5.4”

10.2” x 13.6” x 7”
IGBT’s in VFDs

- IGBT Associated Phenomenon
  - Reflective Wave or $\frac{dv}{dt}$

Long Wires Runs to Motor

Energy stored in distribution system between drive and motor is released during switching and produces voltage spikes.

IGBTs can stress motor insulation because of faster rise times.
The Physics of it All

- Rapid voltage rise times
- The cable surge impedance does not match the motor surge impedance----
  - Voltage reflection WILL occur!!
Reflected Wave Investigation

- **FACT:** Reflected wave voltage at motor is a function of:
  - **Cable Length**
    - Cable distance between VFD and Motor
  - **Output Voltage Risetime**
    - When you turn on the switch (IGBT), how long does it take the voltage being sent to the motor to go from 0 to Max (DC Bus Voltage).
    - Typically in Micro/Nano seconds.
Reflected Wave

Drive

Motor
Effect: Peak voltage levels that search and find insulation voids

- Breakdown, Corona or Partial Discharge of motor windings
- Eventual motor turn-to-turn, winding-to-winding or winding-to-motor frame shorts
Motor Manufacturers Step to the Plate

• Most Manufacturers Now Provide a “Inverter Duty” Product Offering
• Motors are built with “Spike Resistant” Wire
  • Special Coating on Wire to Resist Voids Caused by Their Manufacturing Process, Handling for Forming Prior to Stator Insertion
Protect the Motor

• Output Reactor between drive & motor
  – Slopes off the waveform (lengthens rise time)
  – Reduces destructive force for same amplitude
  – Allows longer lead lengths
  – Does create Voltage drop

• Output Filters
  – $dV/dt$
    • 1204-RWR2, 1204-RWC-17A
    • 1204-TFA1, TFB2 “terminator”
    • Third party devices
  – Sine Wave Filter
    – Distances Beyond 1000’
    – Expensive Solution
GENERATION OF COMMON MODE

or

LINE-GROUND ELECTRICAL NOISE

Common Mode Issues
What is Common Mode Current &
How is it Generated?
IGBT Switching Creating Common Mode Current

Top VI-I output voltage vs. I line-ground stray cable & motor current

Occurs at every IGBT switching
How to Measure Common Mode Current

Current to motor = current from motor.
Resultant should be zero!
Current seen is real current going somewhere?

**Common Mode** to Ground grid.
The Paths of Common Mode Current and it’s affect on Sensitive Electronic Equipment

Common Mode Noise Current Path causing ground EMI Interference
Containing Common Mode Current

CONDUIT PROVIDES GOOD WIRING NOISE CONTROL BUT ACCIDENTAL CONDUIT CONTACT TO GROUND MAY ALLOW $I_{g}$ NOISE PATH BACK TO GROUND
Additional Containment

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 $I_g$ NOISE PATH BACK TO GROUND
Additional Containment

Shielded input & output cable/armor with PVC jacket

PROVIDES BETTER WIRING & NOISE CONTROL WITH NO ACCIDENTAL ARMOR CONTACT TO GROUND. Prevents $I_g$ NOISE interference PATH BACK TO GROUND.
Common mode cores and common mode capacitors as a solution

Implementation of CM core in drive output, CM cores are smaller than output line reactors.
CM ferrite cores attenuate the high frequency noise peak amplitude and more importantly the ILG noise current rise time that develops CM noise ground voltage.
CE or RFI filter solution

* EMI filters re-direct noise current back to drive input leads and out of ground, must be used with shielded output cables.

* (+) and (-) DC Bus capacitors to Ground also perform the same function
Isolation transformer solution

* solidly ground drive isolation XFMR re-directs noise current back to drive input leads and out of ground. Mount close to drive. Must be used with shielded output cables.

* NO Ground noise in upstream ground from XFMR
Using common mode (ferrite) cores on signal wires

Implementation of CM core in signal lines between noisy grounds works
Panel layout is important

Poor panel layout allows $I_{lg}$ noise on output armor to flow back to ground behind the PLC ground, causing possible interference.
Better panel layout allows $I_{ig}$ noise on output armor to flow back to input armor and out of PLC ground.
Strategy to Reduce or Eliminate CM Noise Issues

- Follow grounding recommendations to the letter
- Use recommended panel layout
- Keep motor cables short
- Use shielded cable whenever possible
- Route wires intelligently
- Use drives with CM internal cores
  
or
  
- Use external CM cores
- Set drives for the lowest carrier frequency
QUESTIONS and ANSWERS