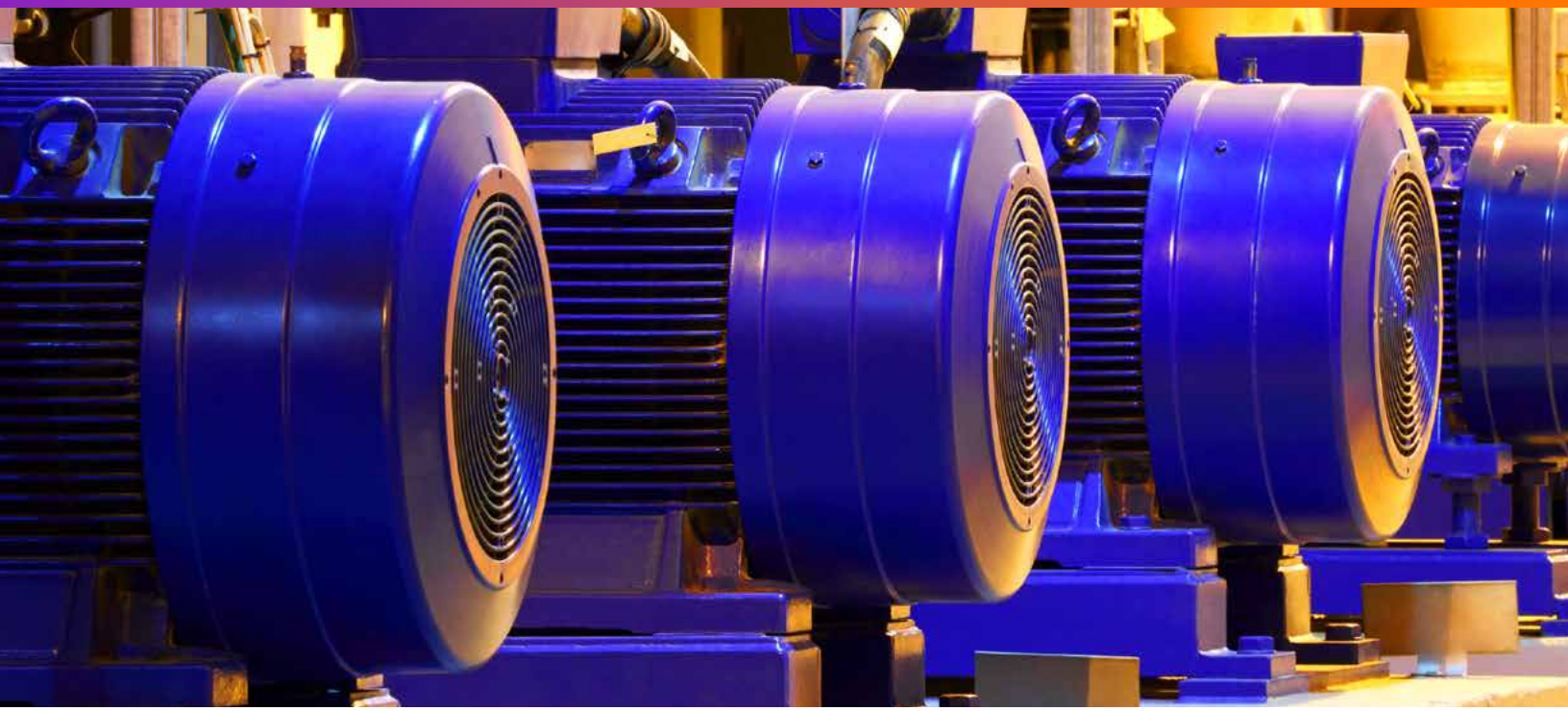
VFD Application Guide

An overview of LAPP cable solutions precision-engineered with robust materials and essential features that satisfy the special demands of VFD-based equipment and their environments.



The Critical Connection: Why Cable Choice Determines VFD System Performance

Between every variable frequency drive and motor lies a critical component often overlooked in system design: the cable. While engineers invest significant effort selecting the optimal VFD and motor, the cable connecting them frequently receives minimal consideration, yet it's where many VFD systems fail.

Standard motor cables are not designed for the electrical environment VFDs create. Consequences may include premature failures, mysterious downtime, interference with sensitive equipment, and motors that never reach their performance potential.

LAPP's ÖLFLEX® VFD family of cables are engineered specifically to handle the unique electrical challenges of VFD applications – not as an afterthought, but as a critical system component designed to maximize drive performance, minimize interference, and ensure long-term reliability.

VFD Electrical Challenges

Cable Charging Current (CCC) & Common Mode Current (CMC)

- IGBT switching creates current ‘surge’ through cable capacitance
- CMC returns via the path of least resistance which often is through the motor bearings, resulting in premature wear
- Most problematic: 480V+ systems, ≤5HP motors

Voltage Spikes

- PWM switching: ~20,000 Hz (vs. 60 Hz line frequency)
- Nominal DC bus voltage can experience rapid voltage spikes during PWM switching
- Places additional electrical stress on motor insulation and cable systems
- Longer cable runs experience more severe voltage stress
- Inadequate insulation = premature failure through voltage puncture

Harmonics

- AC→DC→AC conversion creates distorted waveforms
- Non-linear power stresses motors and cables thermally
- Causes overspeeding, overheating, and equipment confusion
- Radiates back through power system

EMI/RFI Interference

- High-frequency switching generates electromagnetic noise
- Disrupts PLCs, sensors, encoders, and communication systems
- Inadequate shielding allows internal noise to escape, external noise to enter

ÖLFLEX® VFD Product Family Overview						
Product	**Insulation**	**Length***	**Voltage Rating**	**AWG Range**	**Key Features**	**Best Applications**
ÖLFLEX® VFD 1XL **ÖLFLEX® VFD 1XL** ***with Signal***	XLPE (plus)	<300ft	600/1000V	2-16 AWG	30% thinner insulation, smallest OD, global stranding, continuous flex for 1XL without Signal	Space-constrained, conduit fill optimization
ÖLFLEX® VFD 1XLC **ÖLFLEX® VFD 1XLC** ***with Signal***	XLPE (plus)	<300ft	600/1000V	2-16 AWG	Designed for the Canadian market	Canadian tray and exposed run
ÖLFLEX® VFD 2XL **ÖLFLEX® VFD 2XL** ***with Signal***	XLPE (plus)	>300ft	600/1000/2000V	2-16 AWG	Low capacitance design, reduced OD	VFD drive and motor connections; on/off, slow down/speed up applications; long cable runs, HVAC fans, extruders, and heavy machinery
ÖLFLEX® VFD 2XL SYMMETRICAL	XLPE (plus)	>300ft	600/1000/2000V	1 AWG to 500 kcmil	3 symmetrical grounds, helical copper tape	Large HP motors (>150HP)
VFD TGK FLX SYMMETRICAL	XLPE	<300ft	600/1000V	12 AWG to 500 kcmil	3 symmetrical grounds, flexible stranding, foil+braid	Large HP motors, easier routing

**Max cable length also depends on the installed components. Please contact LAPP for specific applications.*

Additional Features

- Tinned copper conductors (oxidation resistance)
- Superior EMI shielding (tri-laminate foil + 85% tinned copper braid)
- Industrial TPE jackets (oil, flame, crush, UV resistant)
- UL TC-ER rating (conduit/armor not required)
- Tight bend radius

XLPE (plus): Premium Low-Capacitance Performance

A cable's conductor insulation is its first line of defense against VFD-generated electrical effects. LAPP's XLPE (plus) insulation design features include:

- Enhanced XLPE formulation withstands 2x dielectric voltage test
- Engineered for minimal capacitance → reduced cable charging current
- Voltage ratings up to 2,000V in standard wall thickness
- Optimal for applications requiring maximum precision and reliability

Common Mode Current Reduction

Cable construction, including the insulation system and a conductor's geometric symmetry, plays a role in influencing common mode current in VFD-driven motor systems. XLPE (plus) insulation systems are designed to reduce capacitive charging current and help limit common mode current compared to conventional cable constructions.

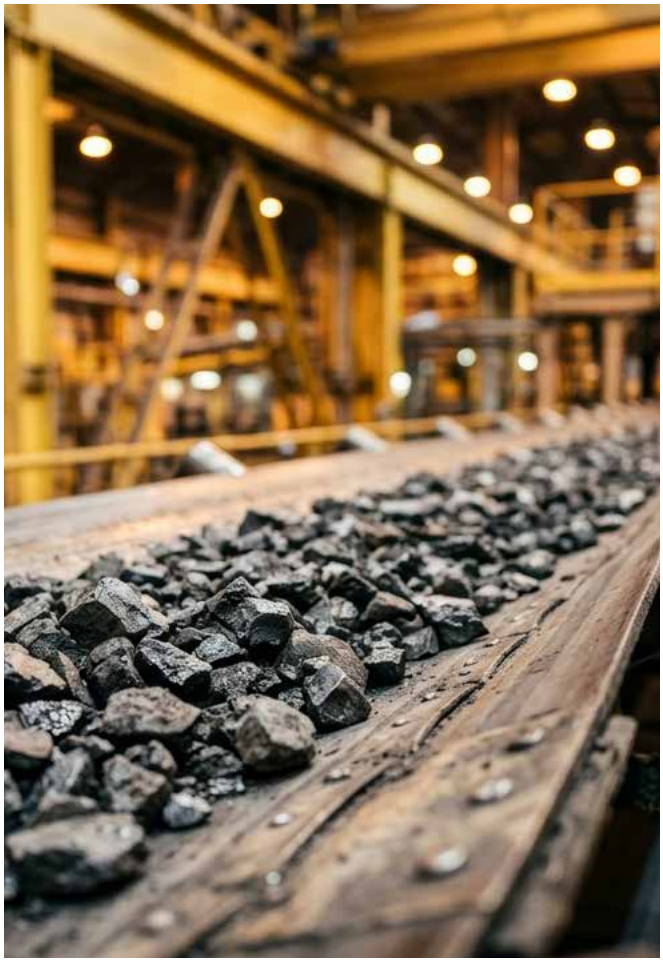
Global Stranding Advantage

LAPP VFD cables use global stranding that complies with both North American (UL, CSA) and European (VDE) standards. Higher circular mil area (CMA) in the conductor results in:

- Lower DC resistance
- Reduced voltage drop across identical AWG-sized cable runs
- Improved current carrying capacity
- Universal termination compatibility

Temperature Performance

- Operating range: -40°C to +105°C (VFD 2XL/1XL)
- Operating range: -40°C to +90°C
- Cold impact tested: -25°C
- Cold bend tested: -40°C



ÖLFLEX® VFD 1XL: Optimized Diameter

- Thin wall technology vs. conventional XHHW-2
- Smallest diameter VFD cable available
- Meets full 600V XHHW-2 requirements
- Global stranding: higher CMA provides lower DC resistance
- Suitable for continuous flex applications

ÖLFLEX® VFD 1XL with Signal

- Reduced diameter
- Robust, oil-resistant and shielded
- XLPE Plus insulation
- UL TC-ER rated for installation without conduit
- Signal pair foil shielded with drain wire

ÖLFLEX® VFD 1XLC: Optimized Diameter

- Rated to TC-ER in Canadian market
- Meets full 600V XHHW-2 requirements at reduced thickness
- Approvals: c(UL) CIC/TC-ER and cRU AWM II A/B FT4

ÖLFLEX® VFD 1XLC with Signal

- Designed for the Canadian market
- Signal pair for brake or temperature control
- Robust, oil-resistant and shielded
- XLPE Plus insulation
- Signal pair foil shielded with drain wire

VFD TGK FLX Symmetrical

- 100% foil and 85% braid coverage for EMI & RFI protection
- Low capacitance design
- UL TC-ER approved with XHHW-2 insulated conductors
- 3-SYM ground design for optimal electrical performance
- Flexible stranding for tight bend radius
- 1000V rated cable

ÖLFLEX® VFD 2XL with Signal

- Oil-resistant according to UL OIL RES I & II
- Flame-retardant according to CSA FT4
- UL Vertical-Tray Flame Test
- EMC compliant
- Sunlight resistant; direct burial
- The 2KV solution
- TC conductors, individually foil shielded with TC drain wire

ÖLFLEX® VFD 2XL Symmetrical

- 100% copper tape shield for EMI & RFI protection
- Low capacitance design
- UL TC-ER & c(UL) CIC/TC approved (CIC/TC approval depending on AWG)
- Three-ground design for optimal electrical performance
- 2000V rated cable

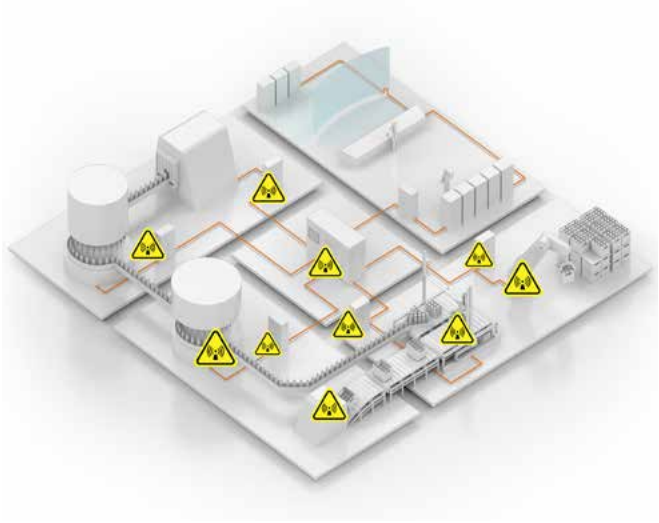
ÖLFLEX® VFD 2XL: The 2kV Solution

- Meets requirements for 2000V rated applications
- 2000V rating enables longer runs without voltage drop concerns
- Low capacitance design
- Specifically formulated TPE jacket

LAPP Superior EMI Shield Construction

Effective shielding serves dual purposes: it contains high-frequency noise generated within the cable and prevents external interference from disrupting signal integrity. LAPP's Super EMI shield construction is designed to manage electromagnetic interference (EMI) in VFD applications. Here is how the construction elements address important EMI requirements.

- Layer 1: Barrier Tape
- Layer 2: Tri-Laminate Foil Tape
- Layer 3: Tinned Copper Braid
- Layer 4: Tinned Copper Drain Wire



Shield Performance

VFD cable shields are designed to reduce EMI generated by high-frequency PWM switching. LAPP VFD cables combine a laminated foil shield and a tinned copper braid to provide high shield coverage and low impedance grounding paths. This shield construction is intended to limit radiated and conducted noise in motor drive installations.

EMI Considerations

High-frequency switching in VFD systems can generate EMI. Shielded motor cables are used to help manage EMI by providing a low-impedance return path and high shield coverage, supporting compliance with system-level EMC requirements when properly installed.

360-Degree Shield Termination

- Pigtail ground methods create high-impedance path at high frequencies
- Incomplete shield contact allows noise escape/ingress

Performance Specs

- IP68, IP69 rated (10 bar pressure)
- NEMA 1, 4X, 6, 12
- Temperature: -40°C to +100°C
- UL, CSA, CE approved

SKINTOP® Cable Gland Solutions				
Gland Type		**Construction**	**Key Features**	**Application**
MS-SC		Ni-plated brass body, internal contact ring	Compact design, reliable contact	Helical copper tape
MS-M BRUSH		Ni-plated brass body, conductive brush ring	Conforms to cable irregularities	Cables with braided shields
MS-NPT BRUSH		Same as MS-M with NPT thread	Type 1, Type 4X, Type 6 and Type 12 acc. to UL 50 E, CSA C22.2 No. 18.3-12	North American threading

Symmetrical Ground Design

Large motors (>200 HP per Rockwell) generate proportionally higher CMC. Equal impedance per phase minimizes common-mode current and voltage imbalance. Impedance imbalance causes bearing currents, shaft voltage and premature motor failure.

The following conditions require symmetrical grounds:

- When motors exceed 200 HP
- Variable speed applications with frequent acceleration/deceleration
- Critical processes where motor bearing failure is unacceptable
- Long cable runs beyond 100 feet

Symmetrical ground conductors are used in high-power VFD applications to provide balanced ground impedance paths. This design is intended to help manage common mode current distribution and reduce electrical stress on motors in large horsepower systems.

Global Stranding

LAPP VFD cables feature stranding that complies with both North American (UL, CSA, Class K) and European (VDE, Class 5) standards, providing:

- Universal termination compatibility
- Optimized flexibility for installation
- Consistent conductor performance across global markets
- Higher CMA for improved electrical characteristics

Ampacity and Sizing

Conductor sizing for VFD applications should follow applicable NEC requirements, including NEC Table 310.15(B)(16), and consider factors such as insulation type, operating temperature, and installation conditions. Proper sizing is essential to ensure reliable operation and compliance with electrical codes.

Jacket Engineering: Industrial Protection

The outer jacket is your cable's defense against the physical environment. LAPP's specially formulated thermoplastic compounds provide multi-faceted protection against oils, and chemicals while maintaining flexibility for tray cable applications.

UL Oil Res II

ÖLFLEX® VFD cables meet UL Oil Res II requirements for resistance to industrial oils when tested in accordance with applicable UL standards. Test requirements include 60 days immersion at 75°C with retention of 65% tensile strength and 65% elongation.

ECOLAB® PM 40-1 Tested

- Wide range of food/beverage/pharmaceutical disinfectants
- Quaternary ammonium compounds
- Chlorine-based sanitizers
- Peroxide cleaners
- Validated for washdown environments

Chemical Resistance

- Cutting oils, hydraulic fluids
- Coolants and lubricants
- Dilute acids and bases
- Alcohols and solvents (refer to chemical resistance chart at lappdigitallibrary.cld.bz/LAPP-2018-NA-Catalog/662/)

Mechanical Protection With TC-ER Rating

UL Type TC-ER cables are evaluated for mechanical durability, including crush and impact resistance, in accordance with UL1569 test requirements. LAPP VFD cables meet these standards for industrial tray cable applications.

Practical advantages include:

- No conduit required for exposed installation (NEC Article 336)
- Can extend beyond industrial structure
- Direct tray-to-motor routing
- Significant labor/material cost savings

Installation Flexibility		
Installation Method	**Standard Motor Cable**	**ÖLFLEX® VFD (TC-ER)**
Cable tray	✓	✓
Exposed along structures	Conduit required	✓ Direct mount
Through walls/barriers	Conduit required	✓ Direct penetration
Outdoor routing	Armored/conduit required	✓ Direct run
Underground	Conduit required	✓ In approved raceway

Flame Resistance & Safety

ÖLFLEX® VFD cables comply with UL 1581 Vertical Tray Flame Test requirements. Testing involves exposure to a 70,000 BTU flame for 20 minutes with maximum char length of 8 feet allowed and self-extinguishing performance required.

CSA FT4 / IEEE 1202 Compliance

- Canadian electrical code requirement
- Similar performance to UL 1581
- Dual certification enables cross-border installations

Environmental Range		
Parameter	**ÖLFLEX® VFD Specification**	**Key Benefit**
Operating temperature	-40°C to +90/105°C	Wide temperature range
Cold bend	-40°C tested	No cracking at extreme cold
Cold impact	-25°C tested	Withstands mechanical shock
UV resistance	Full sunlight rated	Outdoor installation capable
Moisture	Wet/dry rated 90°C	Washdown environments

Rockwell Cable Recommendations Using LAPP					
Where Used	**Max Wire Size**	**Rating/Type**	**LAPP VFD Cable**	**LAPP Voltage**	**LAPP AWG Sizes**
Standard installation 100HP or less	2 AWG	600V, 90C XHHW2/RHW2	ÖLFLEX® VFD 1XL/1XLC (Canada) ÖLFLEX® VFD 2XL	1000V 2000V	16 – 2AWG
Standard installations 100HP or less with brake pair	2 AWG	600V, 90C RHH/RHW2	ÖLFLEX® VFD 2XL with Signal	2000V	16 – 2AWG with signal pair
Standard installations 150HP or more	500 MCM AWG	Tray-rated 600V, 90C RHH/RHW-2	ÖLFLEX® VFD 2XL Symmetrical	2000V	1 AWG – 500MCM
Water, caustic chemical, crush resistance	500 MCM AWG	Tray-rated 600V, 90C RHH/RHW-2	ÖLFLEX® VFD 2XL ÖLFLEX® VFD 2XL with Signal ÖLFLEX® VFD 2XL Symmetrical	2000V	16 AWG – 500MCM
690V application	500 MCM AWG	Tray-rated 2000V, 90C	ÖLFLEX® VFD 2XL ÖLFLEX® VFD 2XL with Signal ÖLFLEX® VFD 2XL Symmetrical	2000V	16 AWG – 500MCM

Rockwell Automation Publication DRIVES-IN001Q-EN-P June 2019.

Engineering Calculations Reference

To ensure VFD cables operate efficiently and reliably, it's important to correctly calculate AWG sizing, voltage drop and run length as shown below:

AWG Sizing for VFD Applications (NEC Article 430-122)

Motor FLC × 125% = Minimum conductor ampacity required

Example: 30 HP, 460V motor

- Full Load Current (FLC) from NEC 430-250: 40A
- Required conductor ampacity: 40A × 1.25 = 50A
- AWG selection from NEC 310.15(B)(16), 60°C column: 6 AWG

Voltage Drop Calculation

VD = Run Length (ft) × Voltage Drop Factor (VDF)

VDF varies by motor HP, voltage, and cable AWG. Contact LAPP for comprehensive VDF tables or use online calculator at lapp-applications.com/product-finder/.

Run Length Optimization

Maximum practical run length is typically limited by:

1. Voltage drop (3-5% maximum)
2. Drive manufacturer cable length specifications
3. Common mode current magnitude

For runs over 300 feet, consult LAPP engineering for application-specific recommendations.

Visit our Eshop to learn more

Regulatory Compliance & Approvals

LAPP VFD cables are tested to satisfy important UL, CSA and other international regulations, and they comply with key European directives. The listings are presented here along with LAPP's rigorous testing capabilities.

UL Listings:

- TC-ER (Tray Cable - Exposed Run): UL 1277
- FMSC (Flexible Motor Supply Cable): 1000V
- Oil Res I & II
- Vertical Tray Flame Test: UL 1581

CSA Certifications:

- CIC/TC (Communication, Instrumentation, Control / Tray Cable)
- TC-ER (Canadian exposed run)
- FT4 Flame Test

Additional:

- CE marked for European installations
- RoHS compliant
- NFPA 79 compliant (Industrial Machinery Standard)
- NEC Article 336 compliant

LAPP Testing Capabilities:

- UL Client Test Data Program (CTDP) laboratory
- CSA Supervised Manufacturers Testing (SMTC) laboratory
- State-of-the-art validation per UL/CSA test methods
- Continuous 5V validation process for quality assurance

The LAPP VFD Cable Advantage

Electrical Performance: XLPE (plus) insulation systems engineered to minimize CCC/CMC, withstand voltage spikes, and handle harmonics.

Superior Shielding: Super EMI shield construction provides high coverage and low impedance grounding for EMI management.

Optimized Conductors: Global stranding, tinned copper, higher CMA for improved electrical characteristics and universal compatibility.

Industrial Durability: TC-ER rated jackets resist oils/chemicals/UV, operate -40°C to +105°C.

Installation Efficiency: Smaller diameters reduce conduit size or eliminate conduit entirely, TC-ER rating enables exposed runs.

Global Applications: Used in a wide range of VFD installations, tested in LAPP's UL/CSA-qualified laboratory.

Built in Region, for Region: Manufacturing presence in 26 locations worldwide to satisfy regional standards and provide local support and fast turnaround time.

Manufactured in North America: LAPP OLFLEX VFD cable products are proudly made in the USA at our state-of-the-art LAPP Cable Works.

No Added Tariffs: Brings clarity and predictability to customer budgeting and production schedules.

For more information or to connect with your local LAPP representative, please visit
https://www.lapp.com/en_US/us/

LAPP