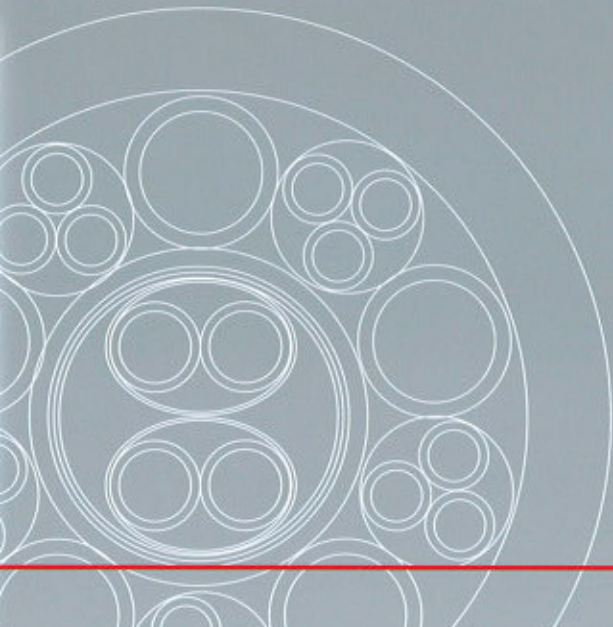




**Motor power supply cables
for speed-controlled
drive systems**



Speed-controlled electric drive systems

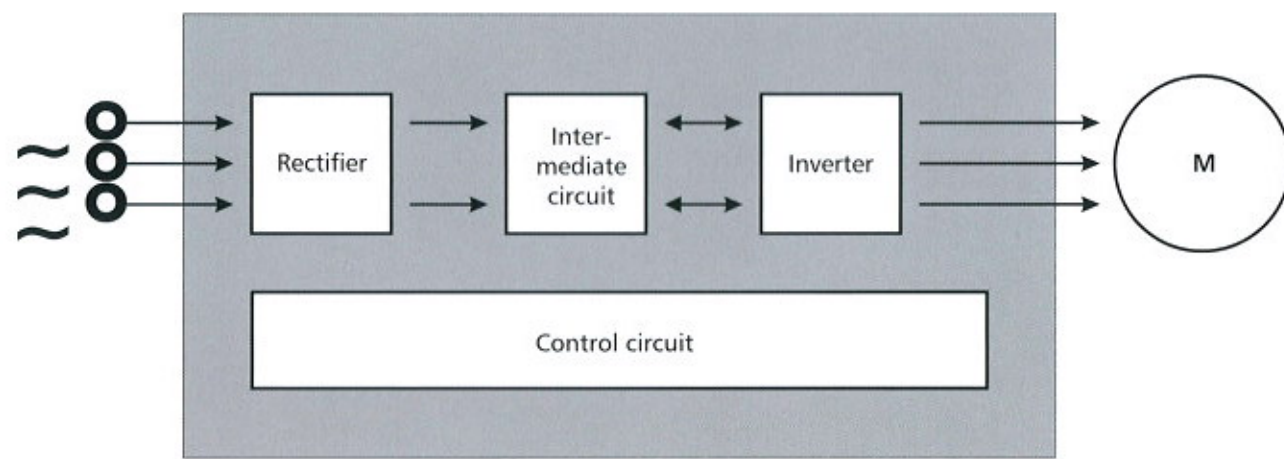
The fundamentals:

The core elements of today's production systems are speed-controlled electric drives.

These are electric motors whose speed can be adjusted continuously depending on the specific application. In these servo drive systems, open-loop and closed-loop control of the speed of the three-phase motor can be adjusted continuously and with

adjusted via the frequency (f) and the motor voltage (u) which are fed in.

This frequency converter is comprised of two IGBT transistor-controlled units. These are the rectifier, which is connected to a three-phase supply with ($f_1 = 50$ Hz), and generates a pulsed direct current, and an inverter, which converts the direct current back to



Functional principle of frequency converter

great precision by means of a frequency converter which generates the engine voltage and engine frequency fed to the three-phase motor.

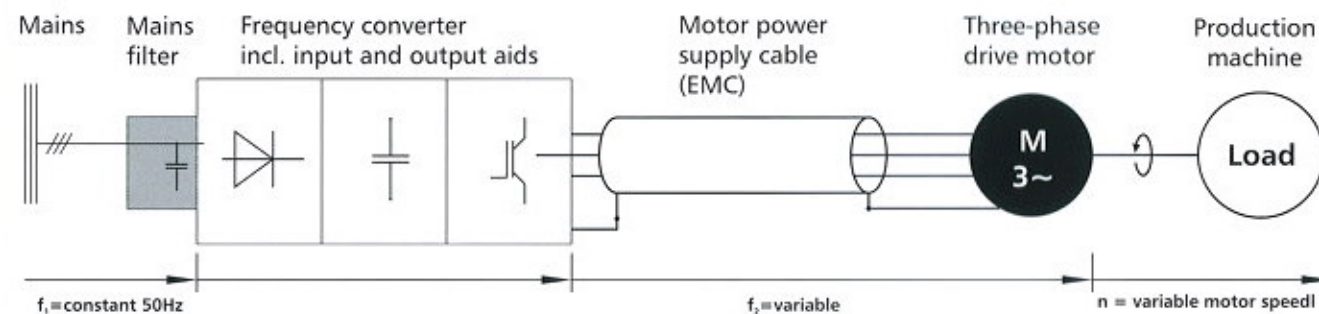
This frequency converter with its control circuit is the most important part of any speed-controlled drive. Open-loop and closed-loop control of the motor speed (n) of the three-phase motor is

a new alternating current with a variable frequency ($f_2 = 0$ to 400 Hz).

This frequency (f_2) is used to control the speed (n) of power supply cable, which makes this technology very efficient.

To put it simply, a complete frequency-converter controlled three-phase drive system (PDS-Power Drive System) consists of the following elements:

In simplified form, a **complete frequency converter controlled three-phase drive system** (PDS Power Drive System) comprises the following elements:



Problems when using speed-controlled electric drives

In addition to major advantages such as continuously variable, precise speed control, frequency converter technology also has certain disadvantages:

- emission of strong electromagnetic interference fields via the motor power supply cable
- high overvoltage in the cable
- large leakage currents and interference currents

For this European standard the max. limit values (quasi peak values) for the interference levels of the radio noise voltage (0.15 MHz to 30 MHz) and the radiated electromagnetic noise (30 MHz to 1,000 MHz) are defined for Category C1: Residential Areas and for Category C3: Industrial Areas.

These EMC limit values must always be observed by adjustable-speed electric drive systems. A distinction is made here between systems in residential and industrial areas.

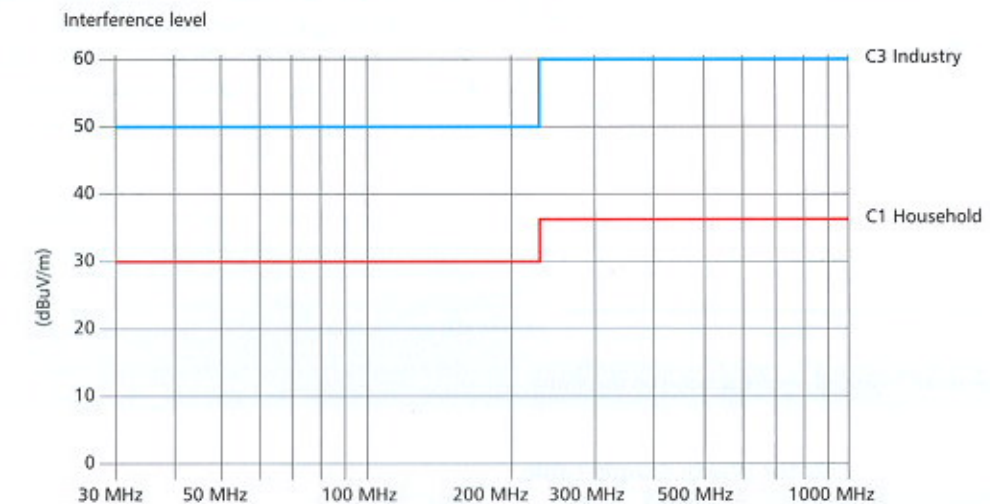
Electromagnetic interference fields and EMC (electromagnetic compatibility) Problems, standards, guidelines

The disadvantage of modern frequency converter systems is that they generate strong electromagnetic interference fields.

The reason for this is the extremely short switch-on and switch-off times of the IGBT transistors (in the nano-second range), and the pulse frequency of up to 20kHz of the frequency converter output voltage.



State-of-the-art stranding machinery at the Windsbach factory



EMC limit values of radiated electromagnetic noise EN 61 800 3

This leads to an extremely large harmonic component in the sinusoidal converter output voltage.

Due to the strong electromagnetic emissions above all from the main source of interference, the motor power supply cable, there is significant interference with the power mains, with the equipment, and with data transmission.

In such cases the European standard EN 61 800-3 (July 2005) can be applied, which specifies the maximum interference level of the drive system in order to ensure that signal transmissions are still protected against interference.

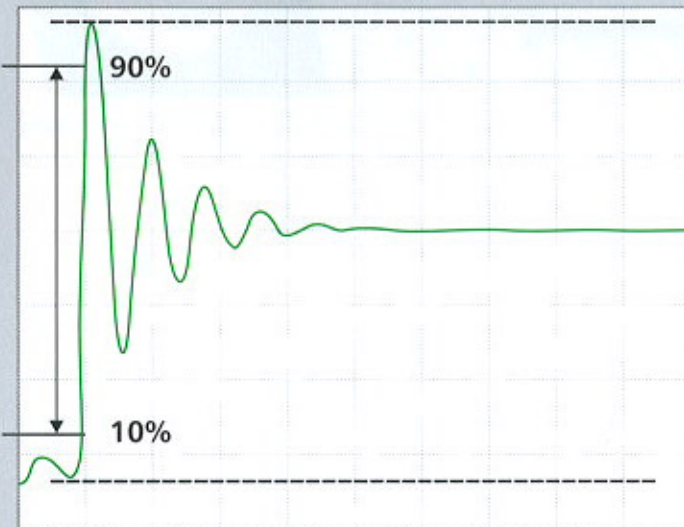
In practice it may happen, for example, that the same frequency-converter controlled heat circulation pump is installed in an industrial facility and in the basement of a residential building. Different EMC limit values apply in these two cases. The pump in the residential area must fulfil stricter requirements (C1) than the one in the industrial facility does (C2).

To successfully fulfil these standards, however, the cables which are installed also have to satisfy the standard. This is only possible with well-shielded cables, and in special cases by also installing mains filters.

Load from overvoltages

The fundamental voltage sent by the frequency converter to the motor power supply cable has a nearly sinusoidal characteristic, and the frequency from 0 to 400 Hz required by the motor speed.

When the characteristic impedance at the beginning and end of the motor power supply cable is changed, impulse waves are generated which in turn generate overvoltages through reflection of the harmonics. This only occurs if the length of the motor power supply cable is greater than the wavelength of the harmonic. With short cable lengths, i.e. if the cable length is shorter than the wavelength, then transient responses appear at the frequency converter output, the result of which is that voltages are generated which are 2 to 3 times greater than the motor voltage. These voltage peaks place a



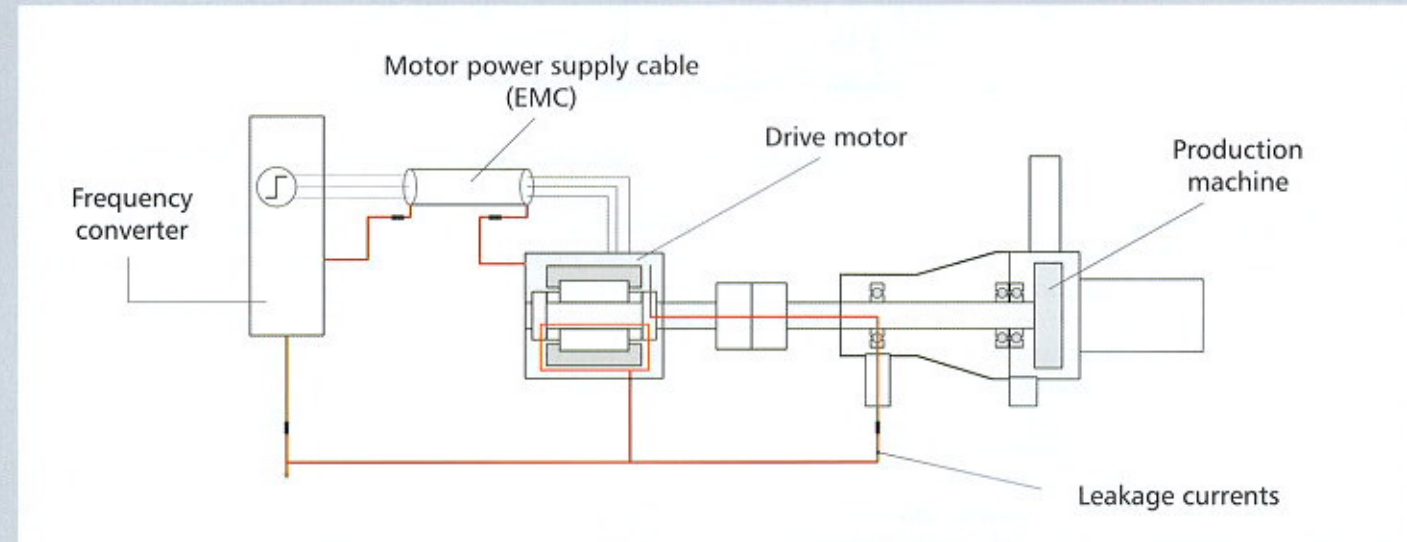
Time characteristic of a voltage pulse on the motor

recurring load on the insulation of the motor power supply cable and the motor coil windings. The insulation of the motor power supply cable must therefore be dimensioned to allow voltage peaks 2 to 3 times greater than the nominal voltage.

Capacitive leakage currents and interference currents

The high frequencies at the converter output mean that high capacitive leakage currents are generated. These high-frequency capacitive open-circuit currents flow over the screen and the motor housing to the earth, and also determine the cross-section of the braided screens and the screen connections. The screen must be constructed in such a way that it is not excessively heated by the current flowing through it. Additionally, high earth capacitances mean that above all with long cable lengths there are large reactive currents which load the frequency converter to such a degree that due to the inverter's overcurrent limit it is no longer possible to transmit the necessary active power to the motor. The currents are then no longer available to generate torque in the motor. At the same time, they flow as large leakage currents over the screen and motor components to earth. These interference currents may also flow through the ball bearing of the motor shaft.

This may cause considerable damage in the form of depressions in the ball bearing rings.



Leakage current paths in a three-phase drive system

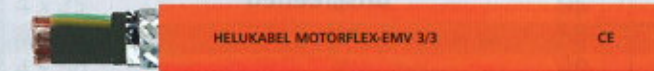
EMC motor power supply cables from HELUKABEL® Requirements, construction and characteristics

In order to compensate for the above-mentioned disadvantages of frequency converter technology, HELUKABEL® offers motor power supply cables with optimised constructions. These special constructions include the TOPFLEX®-EMV and MOTORFLEX-EMV type series, with outstanding characteristics which are described below.

TOPFLEX®-EMV



MOTORFLEX-EMV



High interference immunity

The EMC requirements according to EN 61800-3 are fulfilled by double screening of special aluminium foil and an optimised braided screen tinned copper wire with a coverage of approx. 80%.

The high EMC in the frequency range from 30 to 1,000 MHz can be demonstrated easily using comparative measurements of the radiated electromagnetic noise from unscreened power supply cables and screened EMC power supply cables from HELUKABEL.

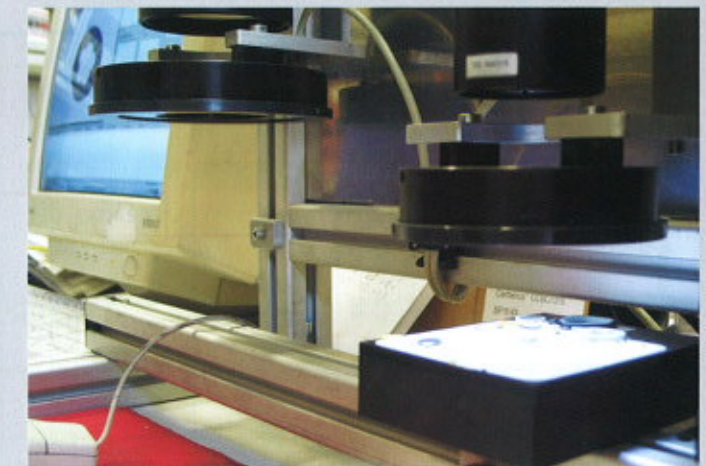


Braiding machine at the Windsbach factory

For the low frequency range from 1 to 30 MHz, the high EMC of the screened EMC motor power supply cables can be seen from the measurement results of an extremely low coupling resistance. The coupling resistance is considered to be a criterion for the screening effect of electrical screen. The lower the coupling resistance, the lower the interference voltage of the power supply interface, and the better the screening effect.

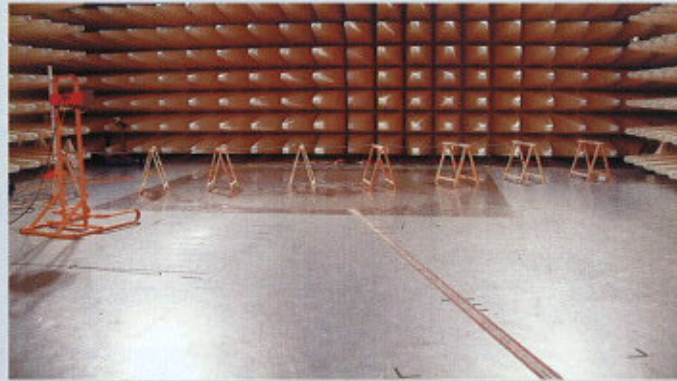


Damage to ball bearing raceway



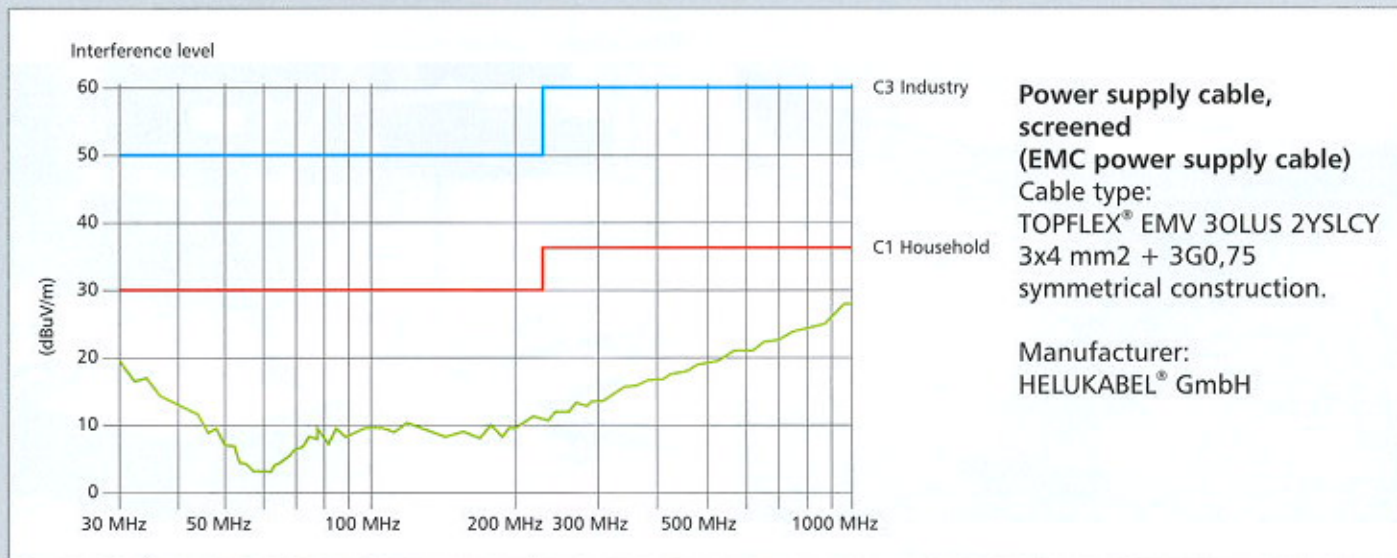
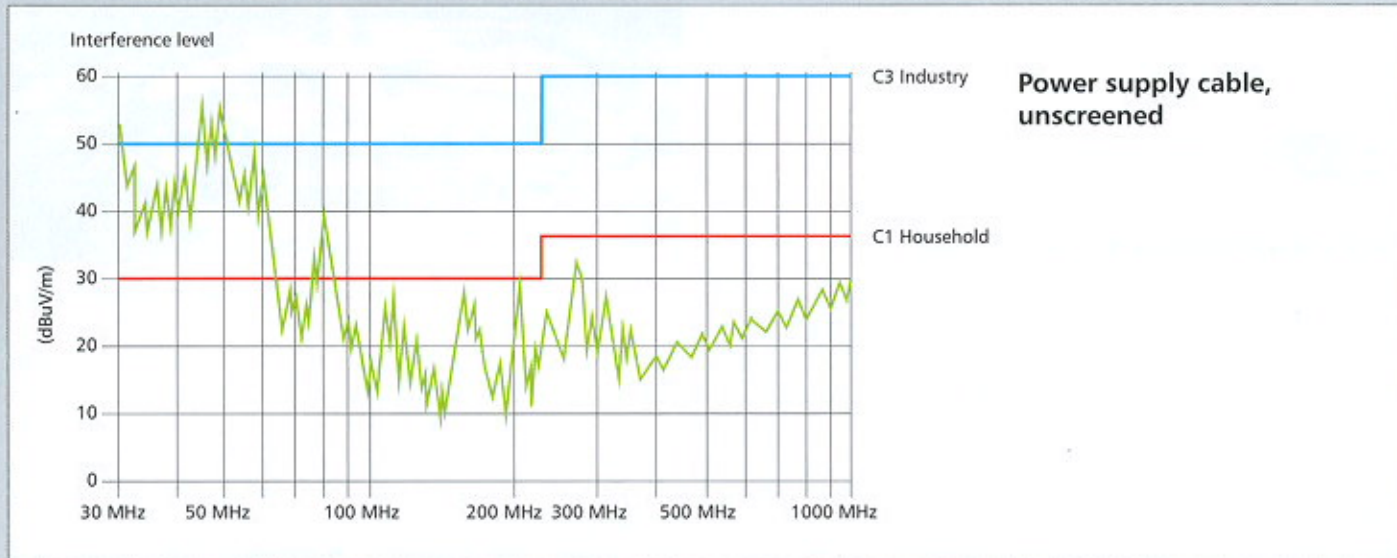
Quality assurance at the Windsbach factory

EMC measurements on motor power supply cables.
The measurements were made in an EMC laboratory.



Cable length 50m, cable approx. 80cm above the floor
Source: Max Fuss, Berlin & University Magdeburg

The results of the interference level measurements show clearly that with the EMC motor power supply cable from HELUKABEL® and optimal screening, the limit values for interference field strength according to EN 61 800-3 will not be exceeded. Moreover, the interference field strengths of the unscreened cable are, especially at low frequencies, significantly below the limit values for industrial and residential areas.



Results of measurements of the coupling resistance Rk/Ohm/km

Cable type: TOPFLEX EMV 2YSLCY J 0.6/1kV
Manufacturer: HELUKABEL GmbH

In the low frequency range between 1 MHz and 30 MHz, a low coupling resistance was measured, resulting in a low interference field strength in the surrounding area.

This ensures a low radio noise field strength for the frequency range from 1 MHz to 30 MHz

No. cross x cross-sec. mm ²	1MHz ohm/km	30 MHz ohm/km
4 x 2,5	18	210
4 x 4	11	210
4 x 6	7	150
4 x 10	6	180
4 x 16	9	190
4 x 25	4	95
4 x 35	3	85
4 x 50	2	40
4 x 70	2	45
4 x 95	1	5

Increased dielectric strength of the motor power supply cable

The core insulation of the motor power supply cable should be made of polyethylene (PE) with good electrical characteristics. The wall thickness of the PE insulation is specially dimensioned to withstand the permanent voltage peaks of twice the value of the converter's nominal voltage.

Nominal voltage: U₀ = 600 V
Max. permissible operating voltage U_b = 1,200 V

Generally the frequency converter output is also equipped with an electrical filter which filters out the high-frequency harmonics and smoothes out the voltage peaks.

Low cable capacitances and low interference currents

The low dielectric constant of 2.3 of the special PE core insulation (2Y) of the EMC motor power supply cable means that it has a lower mutual capacitance and screen capacitance compared to older PVC-insulated motor power supply cables. As a result, the capacitive interference currents are significantly reduced, enabling low-loss power transmission from the converter to the

motor. Moreover, the high quality of the PE insulation gives the cable a long service life. These characteristics are further improved by the symmetrical core structure with three supply cores and an earth core which is divided into thirds (3 + 3 core structure), as in the cable types TOPFLEX EMV 3 PLUS and MOTORFLEX EMV 3/3. This construction reduces mutual capacitance, inductance and capacitive interference currents, leading to further improvement of power transmission from the frequency converter output to the motor input.



Reeling after braiding at the Windsbach factory

Higher current rating with core insulation of cross-linked PE

The current rating of the motor power supply cable can be significantly increased through the use of cross-linked PE (2X) as core insulation. For such cases, HELUKABEL offers the cable type MOTORFLEX EMV 1/1.

The following example compares the maximum current ratings of power supply cables with core insulation of PE (2Y) and cross-linked PE (2X)





No. cross x cross-sec. mm ²	PE (2Y) Ampere	VPE(2X) Ampere
4 x 1,5	18	21
4 x 2,5	26	31
4 x 4	34	40
4 x 6	44	52
4 x 10	61	72
4 x 16	82	96
4 x 25	108	127

HELUKABEL® product assortment

EMC motor power supply cables for frequency converters

Type series TOPFLEX®-EMV 0,6/1kV double-screened
Motor power supply cable based on DIN VDE 0250



Cable type	Cross-section / strand structure	Core insulation	Screening	Outer sheath	Properties	Installation methods	Employment/use
TOPFLEX®-2YSLCY-J 	4x1,5 bis 4x185 mm ² with earth core	Special PE	Double screening 1. Polyester foil coated with aluminium 2. Braid of tinned copper wires	Special transparent PVC	<ul style="list-style-type: none"> - flame retardant acc. to EN 50265-1-2 - EMC requirement acc. to EN 61800-3 - low-loss power transmission 	<ul style="list-style-type: none"> - for fixed installation, occasional free movements - installation in dry, damp and wet environments - not outdoors - in hazardous areas 	Automotive industry Environmental engineering Packaging industry Food industry For pumps, fans, SIMOVERT drives, conveyor belts
TOPFLEX®-UV-2YSLCYK-J 	4x1,5 bis 4x185 mm ² with earth core	Special PE	Double screening 1. Polyester foil coated with aluminium 2. Braid of tinned copper wires	Special black PVC	<ul style="list-style-type: none"> - flame retardant acc. to EN 50265-1-2 - EMC requirement acc. to EN 61800-3 - low-loss power transmission - UV-resistant 	<ul style="list-style-type: none"> - for fixed installation, occasional free movements - installation in dry, damp and wet environments - outdoors - underground installation is possible - in hazardous areas 	Automotive industry Environmental engineering Packaging industry Food industry For pumps, fans, SIMOVERT drives, conveyor belts
TOPFLEX®-3-PLUS 2YSLCY-J 	Symmetrischer Aufbau 3+3x1/3 3x1,5+3x0,25 bis 3x240+3x42,5 mm ² (Earth core divided into 3)	Special PE	Double screening 1. Polyester foil coated with aluminium 2. Braid of tinned copper wires	Special transparent-orange PVC (DESINA)	<ul style="list-style-type: none"> - flame retardant acc. to EN 50265-1-2 - EMC requirement acc. to EN 61800-3 - improved, low-loss power transmission - lower mutual capacitance compared to 4-core construction 	<ul style="list-style-type: none"> - for fixed installation, occasional free movements - installation in dry, damp and wet environments - in hazardous areas - not outdoors 	Automotive industry Environmental engineering Packaging industry Food industry For pumps, fans, SIMOVERT drives, conveyor belts
TOPFLEX®-3-PLUS 2YSLCYK-J 	Symmetrischer Aufbau 3+3x1/3 3x1,5+3x0,25 bis 3x240+3x42,5 mm ² (Earth core divided into 3)	Special PE	Double screening 1. Polyester foil coated with aluminium 2. Braid of tinned copper wires	Special black PVC	<ul style="list-style-type: none"> - flame retardant acc. to EN 50265-1-2 - EMC requirement acc. to EN 61800-3 - low-loss power transmission - lower mutual capacitance compared to 4-core construction 	<ul style="list-style-type: none"> - for fixed installation, occasional free movements - installation in dry, damp and wet environments - underground installation is possible - outdoors - in hazardous areas 	Automotive industry Environmental engineering Packaging industry Food industry For pumps, fans, SIMOVERT drives, conveyor belts

HELUKABEL® product assortment EMC motor power supply cables for frequency converters




Type series MOTOFLEX-EMV triple-screened
Motor power supply cable acc. to UL/CSA Style 20235

Nominal voltage acc. to UL 1000
acc. to VDE 0.6/1kV



HELUKABEL MOTORFLEX-EMV 3/3

CE

Cable type	Cross-section / strand structure	Core insulation	Screening	Outer sheath	Properties	Installation methods	Employment/use
MOTORFLEX EMV 1/1 	4x1,5 bis 4x185 mm ² with earth core	Special PE	triple-screened 1. Semiconducting fleece 2. Polyester foil coated with aluminium 3. Braid of tinned copper wires coverage approx. 85%	Special PUR - extremely abrasion resistant - halogen-free - UV-resistant - microbe-resistant - oil-resistant Sheath colour orange (RAL 2003) according to DESINA	- flame retardant acc. to EN 50265-1 - very good EMC due to triple screening - rugged and abrasion resistant - UV-resistant	- for fixed installation, occasional free movements - installation in dry, damp and wet environments - outdoor installation possible - no underground installation is possible	Power supply cable for heavy mechanical stresses with machine tools, manufacturing robots and conveyor belts.
MOTORFLEX-X EMV 1/1 	4x1,5 bis 4x185 mm ² with earth core	Special cross-linked PE	triple-screened 1. Semiconducting fleece 2. Polyester foil coated with aluminium 3. Braid of tinned copper wires coverage approx. 85%	Special PUR - extremely abrasion resistant - halogen-free, - UV-resistant - microbe-resistant - oil-resistant - flame retardant acc. to EN 50265-1 Sheath colour orange (RAL 2003) according to DESINA	- flame retardant acc. to EN 50265-1 - very good EMC due to triple screening - increased power rating as a result of special cross-linked PE core insulation - rugged and abrasion resistant	- for fixed installation, occasional free movements - installation in dry, damp and wet environments - outdoor installation possible - no underground installation is possible	Power supply cable for heavy mechanical stresses with machine tools, manufacturing machines, industrial robots and conveyor belts.
MOTORFLEX EMV 3/3 	Symmetrischer Aufbau 3+3x1/3 3x1,5+3x0,25 mm ² bis 3x150+3x25 mm ² (Earth core divided into 3)	Special PE	triple-screened 1. Semiconducting fleece 2. Polyester foil coated with aluminium 3. Braid of tinned copper wires coverage approx. 85%	Special PUR - extremely abrasion resistant - halogen-free, - UV-resistant - microbe-resistant - oil-resistant - flame retardant acc. to EN 50265-1 Sheath colour orange (RAL 2003) according to DESINA	- flame retardant acc. to EN 50265-1 - very good EMC due to triple screening - lower mutual capacitance compared to 4-core construction - improved, low-loss power transmission - rugged and abrasion resistant	- for fixed installation, occasional free movements - installation in dry, damp and wet environments - outdoor installation possible - no underground installation is possible	Power supply cable for heavy mechanical stresses with machine tools, manufacturing machines, industrial robots and conveyor belts.



HELUKABEL®

Production Windsbach



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