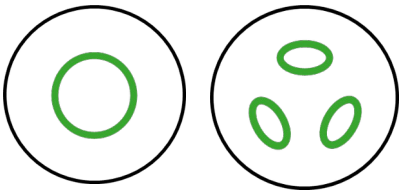
External magnetic fields of pressurized air cables

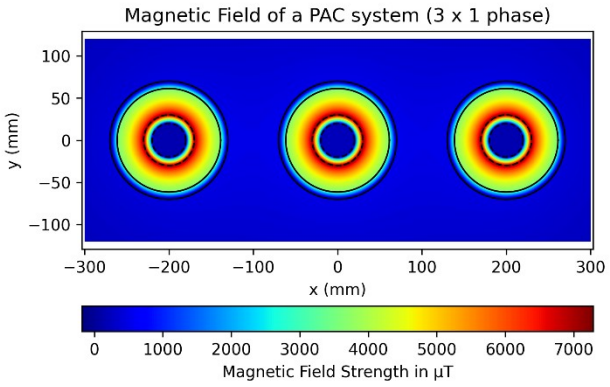


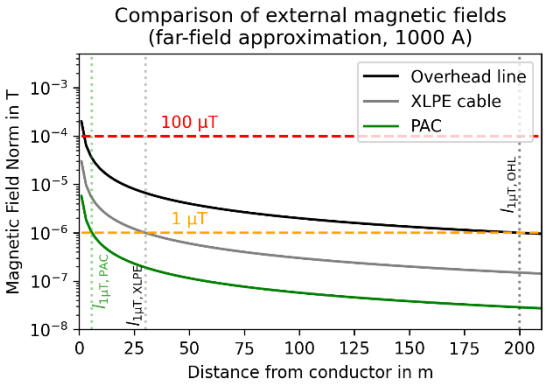
Introduction

External magnetic fields generated by current-carrying conductors are an inherent consequence of electrical power transmission and distribution. These fields increase in strength with current magnitude and proximity to the conductor, and can influence nearby equipment, structures, and personnel. In industrial and infrastructure environments, unmanaged magnetic fields may cause electromagnetic interference (EMI), induce currents in adjacent metallic components, and affect the performance or reliability of sensitive electronic systems. As a result, careful conductor layout, spacing, shielding, and compliance with applicable exposure and EMC standards are essential to ensure operational safety, system integrity, and regulatory alignment.

External magnetic fields calculation and comparison

Assessment of external magnetic fields from high-current conductors is commonly based on distance-to-field-strength criteria, particularly 100 µT ($d_{100\mu T}$ distance) and 1 µT ($d_{1\mu T}$ distance) thresholds. The 100 µT criterion is typically applied to restricted zones close to conductors, where occupational exposure limits, access control, or specific safety measures may be required. The 1 µT criterion is generally used to characterize the broader influence area of the magnetic field, supporting planning decisions related to equipment placement, long-term exposure considerations, and electromagnetic compatibility with sensitive devices. The distances to these thresholds can be determined by finite element simulations. The example below shows the magnetic field inside and outside a 3x1ph enclosed pressurized air cable and its decay with distance:





Hivoduct pressurized air cables employ a coaxial geometry like XLPE cables – but with a major electromagnetic advantage: the current induced in the thick aluminum enclosure largely **cancels the magnetic field of the conductor**, essentially confining the magnetic flux within the cable itself. This design dramatically reduces external magnetic fields compared with overhead lines (see comparison above), enhancing safety, minimizing electromagnetic interference and ensuring compliance with exposure limits – while maintaining efficient power transmission.

Magnetic fields around pressurized air cables

The external magnetic field depends on the product dimensions, the current and – for single-phase enclosed variants – the arrangement of the phases. The table gives a summary of the distance-to-field-strength criteria of pressurized air cable products for various current ratings.

Product	Current per single phase (rms)							
	1000 A		2000 A		3000 A		4000 A	
	$d_{100\mu T}$ in m	$d_{1\mu T}$ in m	$d_{100\mu T}$ in m	$d_{1\mu T}$ in m	$d_{100\mu T}$ in m	$d_{1\mu T}$ in m	$d_{100\mu T}$ in m	$d_{1\mu T}$ in m
145 kV (3x1ph)	0.00	2.20	0.02	3.43	0.09	4.49	0.14	5.50
245 kV (3x1ph)	0.00	1.80	0.01	2.99	0.07	4.00	0.12	4.95
420 kV (3x1ph)	0.00	1.64	0.00	2.72	0.00	3.64	0.00	4.50
52 kV (3ph)	0.10	2.06	0.19	2.97	0.25	3.68	n/a	n/a
145 kV (3ph)	0.04	2.00	0.13	2.91	0.20	3.62	0.25	4.24
245 kV (3ph)	0.00	1.96	0.08	2.88	0.15	3.59	0.21	4.19

Notes: Distances measured from the enclosure surface. The 3x1ph configurations are horizontal arrangements as shown in the figure above. All values apply to long, straight installations. Distances refer to the peak value of the magnetic field. Smaller spacing between single-phase cables or a three-phase design reduces external fields.

The magnetic field of a single overhead line carrying 1000 A extends to 2 m (100 µT) and 200 m (1 µT). In comparison, the magnetic field of a 145 kV 3ph pressurized air cable only reaches 0.04 m (100 µT) and 2 m (1 µT), respectively.

Hivoduct's pressurized air cables **substantially outperform** overhead lines and XLPE cables of similar current ratings in suppressing the external magnetic field.

Other features of the rigid metallic enclosure

In addition to damping magnetic fields, the rigid aluminum enclosure of pressurized air cables offers further benefits: grounding, mechanical rigidity, fire protection, protection against external damage, containment of internal arc faults, cooling, and reduced forces in case of short-circuit currents.

The large enclosure cross section (larger than the conductor cross section) can carry the full rated current with low additional losses. The enclosure can therefore be **grounded at every available grounding point**. This simplifies grounding compared with the cross-bonding of XLPE cables and provides the best protection against touch voltages.

The rigid enclosure additionally protects the cable from mechanical damage (by accident or by vandalism) and provides stiffness and mechanical support. This is advantageous in exposed sections, to simplify supporting structures, and for vertical installations.

The high bursting pressure of the enclosure (57.5 bar) is a safety measure for enclosures acting as pressure vessels. As a result, it also remains tight in the rare case of an internal arc fault. An internal arc fault damages internal parts – but the enclosure contains it and thus protects nearby infrastructure and personnel.

The continuous metallic enclosure protects the cable from fire and does not add fire load to surrounding infrastructure. This allows installations in service tunnels and other linear infrastructure.

Heat from the conductor is effectively transferred to the enclosure via radiation and convection of the inside pressurized air. The enclosure efficiently distributes heat along the line and emits heat to the environment.

Cancelling the external magnetic field during operation and during short circuits results in **little to no reaction forces** between phases or between phase and ground. The fixations can therefore be optimized for weight and earthquake requirements. Reaction forces during short-circuit events are comparatively small.