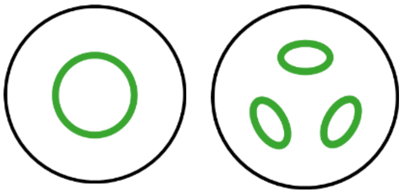
External Magnetic Fields of Pressurized Air Cables

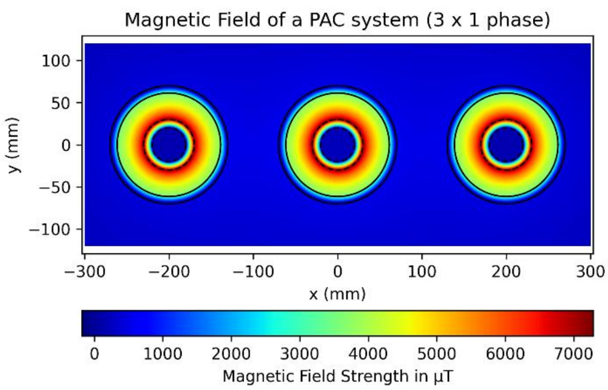


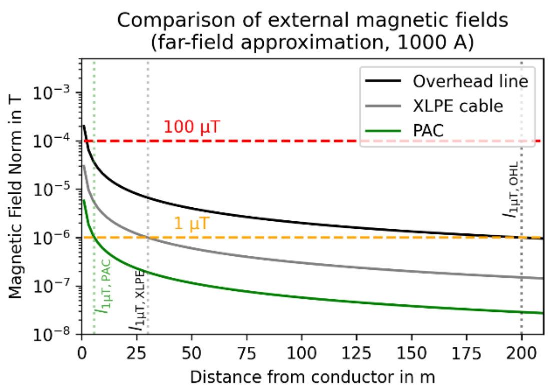
Introduction

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 for AC currents

Assessment of external magnetic fields from high-current conductors is commonly based on distance-to-field-strength criteria, particularly 100 µT ($l_{100\mu T}$ distance) and 1 µT ($l_{1\mu T}$ 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 distance to the thresholds can be simulated using finite element methods simulations. An example is shown below for the magnetic field inside and outside of 3x1ph enclosed pressurized air cables and its decay with distance:





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

Magnetic fields around pressurized air cables

The outside magnetic field depends on the product dimensions, the rated current and the arrangement in single-phase enclosed variants. 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 (3 x 1ph)	0.00	2.20	0.02	3.43	0.09	4.49	0.14	5.50
245 kV (3 x 1ph)	0.00	1.80	0.01	2.99	0.07	4.00	0.12	4.95
420 kV (3 x 1ph)	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		
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: Distance measured from the enclosure. The 3 x 1ph configurations are horizontal layouts as shown in the picture above. All options are long, straight installations. Distances are given for peak value of magnetic field. Less spacing between 1ph cables or employing a 3ph option reduces outside 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 reach 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 additional safety features: Grounding, mechanical rigidity, fire protection, protection from outside damaging, protection against internal arc faults, and cooling.

The large enclosure cross section (larger than conductor cross section) can carry the full rated current without adding too many losses. The enclosure can therefore be **grounded at every possible grounding point**. This simplifies grounding compared to cross-bonding of XLPE cables and provides best protection against touching 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 (> 50 bar) is a safety measure for enclosures acting as pressure vessels. As a result, it also holds tight in the rare case of an internal arc fault. Internal arc faults will damage internal parts – but the enclosure keeps it internally and thus prevents danger to nearby infrastructure or 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.