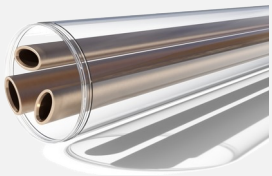
Technology comparison: pressurized air cable (PAC) vs. XLPE cable

Pressurized air cable or XLPE cable? The following tables compare system parameters, economy, environment and society, and technical parameters[1]. All values are typical values for current products or projects and may vary depending on the application.

Comparison: system parameters

Topic	XLPE cable 	Pressurized air cable (PAC) 
Main layout	Underground, concrete-encased cable duct block	Underground: microtunnel, pipe, or walkable tunnel.
Space requirement	Corridor 145 kV: ≈ 2.0 m Corridor 245 kV: ≈ 2.6 m Corridor 420 kV: ≈ 3.5 m	Pipe 145 kV: Ø 0.7 m Pipe 245 kV: Ø 1.0 m Pipe 420 kV: Ø 1.2 m
Construction along the line	Wide trench for duct block. Jointing pit every ~1000 m	Pipe. Installation pit every ~300–500 m.
Line losses at I = 1000 A (scales with I^2)	145 kV: ~50 kW/km 245 kV: ~45 kW/km 420 kV: ~30 kW/km	145 kV: ~46 kW/km 245 kV: ~25 kW/km 420 kV: ~19 kW/km
Transmission power (typical values)	145 kV: ~400 MW 245 kV: ~900 MW 420 kV: ~2300 MW	145 kV: ~800 MW 245 kV: ~1600 MW 420 kV: ~3600 MW
Large-scale use in the grid?	Limited: Resonances, reactive power requirement	Not yet. Complete replacement of the overhead line grid possible.
Operational experience	Extensive operational experience at all voltage levels	New technology. Experience similar to GIL or GIS.
Fault location	Distance protection, impedance method.	Integrated in pressure monitoring: indicates the gas compartment
Repair in case of fault	Difficult repair. Jointing. No standard spare parts.	Repair per busduct. Standard spare parts.
Repair duration	Weeks to months	Several days
Parallel systems	Required for redundancy and high transmission power	Only for redundancy
Parallel systems (high currents)	Required for > 2000 A	Not required up to 4000 A
Monitoring in operation	Additional monitoring systems,	Integrated pressure monitoring

[1] Focus on voltage levels ≥ 145 kV. PAC can also be used at medium voltage.

	e.g. PD, DTS, sheath	for all key parameters
Grounding	Cross-bonding with SVL to limit losses	Enclosure grounding at every available ground connection
Voltage upgrade 245 kV → 420 kV	Needed to reduce losses and increase transmission power	Optional to reduce losses and increase transmission power
Options for upgrade and grid enhancement	Can only replace sections of OHL	Continuous expansion of the grid possible
Exposure (as critical infrastructure)	Underground. Protected by duct block. Exposed interfaces.	Underground. Protected access. Rigid metallic enclosure.

Comparison: Economy

Topic	XLPE cable	Pressurized air cable (PAC)
Investment cost: Line plus installation[2] **(without approval costs)**	145 kV: ~1.2 MCHF/km 245 kV: ~2.7 MCHF/km 420 kV: ~5.0 MCHF/km	145 kV: ~1.5 MCHF/km 245 kV: ~2.9 MCHF/km 420 kV: ~4.3 MCHF/km
Cost of electrical losses over 40 years of operation at an average of 1000 A	145 kV: ~2.1 MCHF/km 245 kV: ~1.6 MCHF/km 420 kV: ~1.0 MCHF/km	145 kV: ~1.0 MCHF/km 245 kV: ~0.6 MCHF/km 420 kV: ~0.4 MCHF/km
Cost dependency on rated current	Strong dependency: higher current → higher cost	Low dependency: one base design for all currents
Economic limit to line length	Limited by reactive power and resonances	No limit in modern grids with battery storage
Cost of reactive power compensation	Significant for > 20 km length	None up to ~60 km length. Needed for > 60 km length.
Delivery time: Cables, pipes	Years	~Months
Cost for jointing pits, installation pits	~20 kCHF/pit	~20 kCHF/pit
Operation and maintenance	Low maintenance effort.	Low effort. Integrated monitoring system.
Installation process	Trenching, concrete pouring, cable pulling, jointing.	Lay pipe or drill microtunnel. Connect tubes and roll them in.
Public tendering	Standardized. Many established suppliers.	No product-specific tenders yet. Single supplier.
Expected lifetime	~40 years	> 40 years (like GIS)

Comparison: Environment and society

Topic	XLPE cable	Pressurized air cable (PAC)
Approval process for line projects	Lengthy (cable duct block). Project-specific routes.	Faster due to zero emissions. Existing corridors can be used.
Public acceptance	Poor during construction.	No reference yet. Expected to

[2] Typical values for long, mostly straight installations.

	Better than OHL.	be better due to zero emissions.
External electric fields	None: shielded.	None: metallic enclosure.
External magnetic fields at 1000 A	< 100 µT in > 1.0 m distance < 1 µT in > 10 m distance	< 100 µT in > 0.3 m distance < 1 µT in > 3.0 m distance
Safety risks	Fire. Internal arc fault. Grounding error.	Large pressure vessel (~10 bar)
Exposure to vandalism, sabotage, terrorism	Slightly increased: arson attacks, mechanical damage.	Minimal: underground, locked access, rigid enclosure
Emissions to environment	Magnetic fields, heat, concrete ducts	Minimal emissions.
Effects on neighborhood	Limited effect from EM fields.	Minimal effects.
Recycling at end of life	Metal conductors recyclable. Insulation material: disposal	~99 % aluminum. Fully recyclable.

Comparison: Technical parameters

Topic	XLPE cable	Pressurized air cable (PAC)
Design and installation	Complex design & extrusion. On-site jointing needed.	Simple assembly. Installation in pits with special tools.
Insulation medium	Cross-linked PE (XLPE)	Pressurized air (~10 bar, dry)
Conductor material	Aluminum, copper	Aluminum
Field stress on conductor during operation	~10–18 kV/mm	2–4 kV/mm
Shielding / enclosure	Thin conductive screen	Thick aluminum enclosure
Fire protection	Insulation: Can burn and produce smoke.	Metallic enclosure: Non-flammable.
Conductor cross section (Single wire or bundles)	240–2500 mm^2	Minimum: 2200 mm^2 Maximum: 5000 mm^2
AC resistance at operating temperature	145 kV: ~26 mΩ/km 245 kV: ~24 mΩ/km 420 kV: ~20 mΩ/km	145 kV: 12 mΩ/km 245 kV: 10 mΩ/km 420 kV: 8 mΩ/km
Capacitance per km	145 kV: ~160 nF/km 245 kV: ~140 nF/km 420 kV: ~140 nF/km	145 kV: ~50 nF/km 245 kV: ~50 nF/km 420 kV: ~50 nF/km
Charging current per km per phase at rated voltage	145 kV: ~4.2 A/km 245 kV: ~6.2 A/km 420 kV: ~10.7 A/km	145 kV: ~1.30 A/km 245 kV: ~2.22 A/km 420 kV: ~3.81 A/km
Reactive power, 3 phases	145 kV: ~1.1 MVAr/km 245 kV: ~2.64 MVAr/km 420 kV: ~7.76 MVAr/km	145 kV: ~0.33 MVAr/km 245 kV: ~0.94 MVAr/km 420 kV: ~2.80 MVAr/km
Reactive power compensation	Required for > 20 km length	Required for > 60 km length
Bending radius	Typical: 20–30 × D.	Continuous bending or

	~2–3 m bending radius	90° angles if required
Internal arc fault withstand	None. Internal arc fault leads to cable fire.	Yes. Arc remains inside; pressure stays below bursting pressure.
Temporary overloading	Poor due to thermal insulation by the XLPE layer.	> 1 h at 1.5 × I_r. Good heat dissipation via metal enclosure.
On-site testing after installation	High inductance (resonant test) required for long cable sections.	Testing of individual sections; lower capacitance.