



OFIL SYSTEMS

NEWSLETTER

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765 kV EHV Transmission: Power Highways Supporting Grid Expansion and Energy Transition

As power systems worldwide scale to meet unprecedented demand, from electrification and industrial growth to hyperscale data centers and large-scale renewables - 765 kV extra-high-voltage (EHV) AC transmission lines are increasingly considered in long-term transmission planning. These “power highways” move massive blocks of electricity over long distances with fewer circuits, lower losses, and improved overall system efficiency.

What are 765 kV lines?

Operating among the highest AC transmission voltages in commercial service, 765 kV lines are typically built as overhead systems using tall steel lattice towers (about 130–180 ft) with long spans that can reach roughly 1,400 ft. A single 765 kV circuit can transmit the equivalent power of three 500 kV lines or up to six 345 kV single circuits, dramatically increasing power density per corridor and reducing the need for multiple parallel rights-of-way.

Where are they used?

Large-scale 735/765 kV networks have been in service for decades in Québec (Canada) and across parts of the United States, particularly in systems originally developed by major utilities such as AEP and NYPA. Globally, similar voltage classes (often referred to as ~750–787 kV) have been deployed in Brazil, Venezuela, South Africa, South Korea, India, Japan, and across regions of the former USSR forming long-distance corridors linking major generation centers to load hubs.

Why utilities invest in 765 kV

The primary driver is simple physics and economics: transmitting large power blocks over hundreds of kilometers at very high voltage significantly reduces I^2R losses and minimizes land use compared with multiple lower-voltage lines. Today, 765 kV backbones are increasingly considered to:

- Integrate remote renewable generation at scale.
- Support rapid growth of data centers and industrial loads.
- Relieve congestion on existing 345–500 kV networks.
- Improve grid resilience by offloading stressed lower-voltage corridors.

In many long-term grid plans, 765 kV acts as a high-capacity overlay that strengthens the entire transmission system beneath it.



The Technical Reality at 765 kV: Corona and Insulation Take Center Stage

At these voltage levels, corona discharge and insulation design are no longer secondary concerns - they are central technical constraints that shape every aspect of the line.

Corona-related challenges:

High electric field stress and corona onset

At 765 kV, surface electric fields on conductors, clamps, and fittings can easily exceed air ionization thresholds. Even small geometric irregularities may trigger corona, leading to:

- Corona power losses (kW per km).
- Audible noise and visible glow.
- Ozone and nitrogen oxides generation.
- Radio and TV interference that must remain within regulatory limits.

Hardware design and aging under corona

To control these effects, connectors, clamps, grading rings, and end fittings require meticulous shaping—often validated through advanced 3D electric-field simulations and laboratory testing. If corona is not fully suppressed, especially on polymer or composite components, accelerated aging and degradation can occur, ultimately reducing insulation life and increasing maintenance costs.

Insulation and clearance challenges:

- **Air clearances and insulation coordination** - Insulation coordination at 765 kV demands very large phase-to-phase and phase-to-structure clearances to withstand lightning and switching overvoltages with adequate safety margins. Utilities frequently specify design criteria beyond minimum codes, resulting in physically larger towers, substations, and buswork—all contributing to higher CAPEX.
- **Insulators, pollution, and icing** - Long insulator strings or tall post stacks with optimized shed profiles are required to achieve sufficient creepage distance under pollution, wetting, or icing conditions. Grading and corona rings are essential to control voltage distribution and local electric fields. In harsh environments, selecting and maintaining these insulation systems becomes increasingly complex at 765 kV.

System-Level Implications: Cost, Complexity, and the Need for Advanced Diagnostics

Operating at 765 kV creates a challenging electromagnetic environment along the right-of-way. Corona-related noise and interference tend to worsen over time as conductors age and surface conditions degrade. This reality drives design choices such as bundled conductors, larger bundle spacing, and extensive use of grading hardware.

From a lifecycle perspective, the cost and complexity of 765 kV assets make proactive inspection and condition-based maintenance essential. Any surface damage, contamination, or hardware modification can reintroduce corona and erode carefully designed insulation margins.

This is where advanced diagnostic tools become critical. Non-contact inspection technologies such as solar-blind UV imaging enable utilities to detect and precisely locate corona and partial discharge activity from a safe distance, even in daylight conditions. Early identification of abnormal corona allows corrective action before minor surface issues escalate into insulation failures, outages, or regulatory complaints.

Commissioning at 765 kV: Verifying Corona Performance at Initial Energization

The commissioning phase is the first opportunity to evaluate how a 765 kV transmission system performs under real electrical stress conditions. At this stage, theoretical design margins and construction quality are tested against operating voltages approaching the limits of air insulation. Due to the extremely high electric fields involved, even small deviations in geometry, surface condition, or hardware installation can give rise to corona or partial discharge activity that is not detectable through conventional visual inspection methods.

During commissioning, solar-blind ultraviolet (UV) inspection serves as a critical validation tool for identifying corona and partial discharge activity that may not be apparent through standard visual or electrical tests. At 765 kV, defects related to design tolerances, manufacturing variability, transport damage, or installation errors such as misaligned fittings, missing or improperly installed grading rings, or damaged spacers can become active discharge sites once voltage is applied. Non-contact UV scanning allows utilities and EPC teams to directly visualize and localize these sources of electrical stress, enabling corrective action before the asset enters continuous operation and while contractual and warranty responsibilities are still clearly defined.

Beyond resolving immediate commissioning findings, UV inspections performed at initial energization establish a clean and reliable baseline of corona performance for each asset. This baseline provides a reference against which future inspections can be compared, supporting condition-based maintenance and early detection of emerging degradation. When incorporated into digital inspection and asset-management workflows, commissioning-time UV data forms the foundation for long-term performance monitoring, risk prioritization, and lifecycle management of high-value 765 kV transmission infrastructure.

Looking Ahead

Although 765 kV transmission projects involve significant capital investment and complex planning and permitting processes, they continue to be considered by utilities as part of long-term strategies for bulk power transfer, grid reinforcement, and integration of large-scale generation. As transmission systems expand while portions of the existing EHV infrastructure age, maintaining reliable operation at these voltage levels increasingly depends on both robust design practices and effective condition monitoring throughout the asset lifecycle.

At 765 kV, corona activity and insulation performance are key technical factors influencing power losses, electromagnetic interference, environmental impact, and long-term asset reliability. For this reason, many utilities supplement conventional maintenance programs with condition-based inspection approaches. Non-contact diagnostic techniques, including solar-blind ultraviolet imaging, allow daylight detection and localization of corona and partial discharge activity on conductors, fittings, and insulation hardware. When incorporated into routine inspection and asset-management workflows, such tools support early identification of abnormal conditions, trending over time, and more informed maintenance prioritization for EHV transmission assets.

Wind Turbine Fires and Partial Discharge Why early UV detection matters from factory to field

Wind turbines and how they feed the grid

A wind turbine converts wind energy into rotational motion and uses a generator in the nacelle to produce AC electricity. Because wind speed constantly changes, the generator's electrical output naturally varies as well. Modern turbines therefore rely on power electronics (converter/inverter systems) to condition the generated power and export grid-compatible AC with controlled voltage and frequency.

This architecture makes the turbine not only a mechanical machine, but a continuously operating high-energy electrical asset connected to the collection network and, through a substation, to the wider power system.



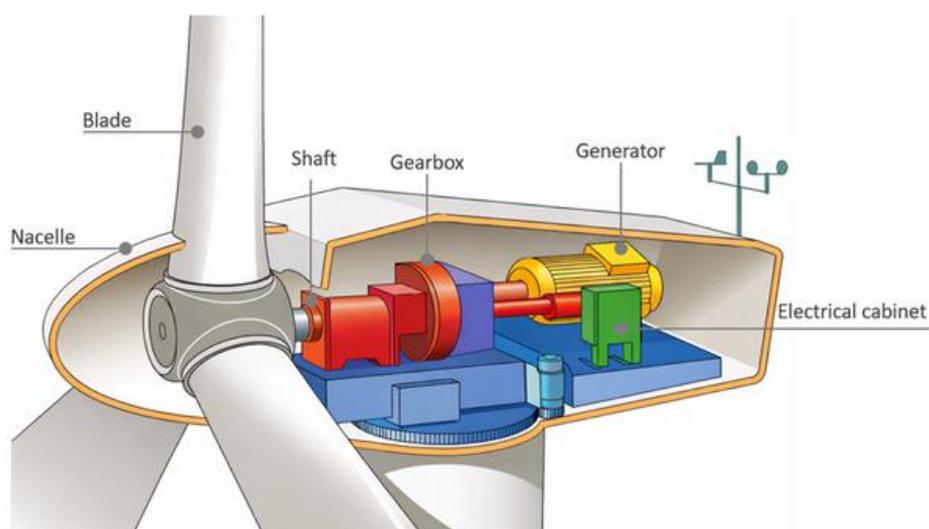
What's inside the turbine and where electrical stress concentrates

A utility-scale turbine packages multiple electrical subsystems into a compact nacelle, with additional power equipment distributed down the tower. Typical building blocks include the drive train, generator, converter cabinets, transformer (nacelle or tower base, depending on design), and long cable runs with multiple connectors and terminations.

From an insulation and reliability standpoint, the highest electrical stress tends to concentrate at:

- Generator stator windings and end-windings
- Converter-connected cabling, joints, and terminations
- Interfaces inside electrical cabinets where clearances, edges, contamination, or vibration can create localized high electric fields

These are also the locations where early electrical activity can begin long before any visible damage appears.



Fire risk in wind turbines — and the link to partial discharge

Wind turbine fires are low-frequency but high-consequence events. When a nacelle fire occurs, the practical response is often limited by turbine height, remote terrain/offshore access, and the difficulty of applying water or foam effectively at the source. As a result, incidents are frequently allowed to burn out, and industry sources note that major damage or total loss is common without suppression.

The ignition pathway can vary. Some causes can be lightning-related surges, mechanical failures (e.g., bearings/brakes), hydraulic system leaks near hot surfaces, and electrical faults in the nacelle. Independent reviews and long-term incident analyses have also pointed out that fire represents a meaningful portion of reported turbine accidents and can lead to significant downtime or full turbine loss.

This is where partial discharge becomes relevant. PD is not a “fire event,” but it can be an early-stage electrical mechanism that gradually erodes insulation. Over time, that degradation can progress into arcing, and arcing is one of the direct ways an electrical defect turns into ignition inside the nacelle’s confined environment.



Partial discharge in wind turbines — and UV detection during design, installation, and service

Partial discharge (PD) is a localized electrical discharge that does not fully bridge insulation, but gradually degrades it over time. In inverter-fed wind-turbine generators, fast switching and high dv/dt increase electrical stress on insulation systems—especially around winding end-turns, terminations, and cable interfaces.

Because PD can repeat for long periods, it is treated as a major reliability risk: ongoing discharge activity can erode insulation until it progresses into tracking and arcing, which are direct precursors to catastrophic failures.

This matters in the broader context of turbine fire risk. Fire statistics vary and are affected by under-reporting, but multiple sources describe fire as a meaningful share of catastrophic turbine incidents (often cited in the 10–30% range), with outcomes that frequently include major downtime or total loss. Some industry estimates also cite 114 wind-turbine fires in 2024, with €2–3 million in losses per turbine.

To manage PD risk, manufacturers and specialist labs use dedicated verification methods such as surge (impulse) testing—typically around 1,500–4,000 V—to reveal weak points and characterize insulation robustness. Design and manufacturing choices also play a major role, including insulation system selection, winding geometry, and impregnation processes, which can improve resistance to PD stress even if they do not eliminate PD entirely.

Where UV cameras fit

Solar-blind UV cameras detect UV emissions associated with corona PD. In practice, they are useful because they can reveal active discharge earlier than methods that depend on heat or visible damage.

- **Design & manufacturing (before shipment):** UV inspection can be used as a quality check to confirm there is no active corona/PD activity around key insulation areas and terminations, complementing standard electrical verification tests (such as surge/PD tests) used to validate insulation robustness.
- **Installation & commissioning (before handover):** UV inspection helps verify that terminations, connectors, and cabinet interfaces are “clean” under operating conditions, catching issues introduced by installation (clearance problems, sharp points, contamination) before the turbine enters long-term service.
- **Service & maintenance (condition-based):** UV inspection helps detect developing discharge sites before they escalate into arcing. In the fire context, this is the key value: intervening while the problem is still electrical activity rather than a fault event reduces the chance of a high-impact nacelle incident.

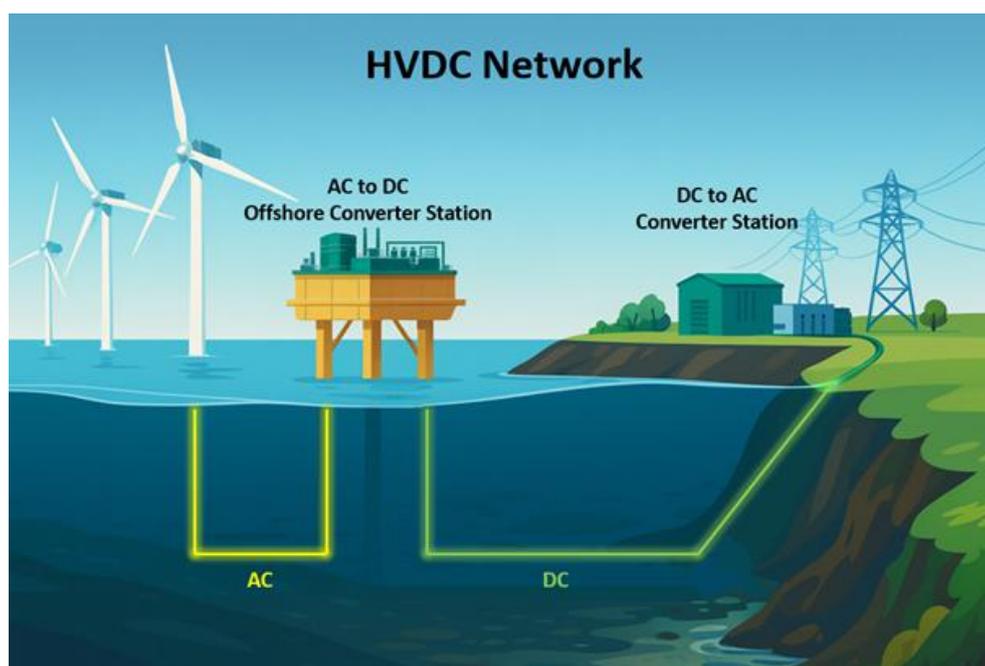
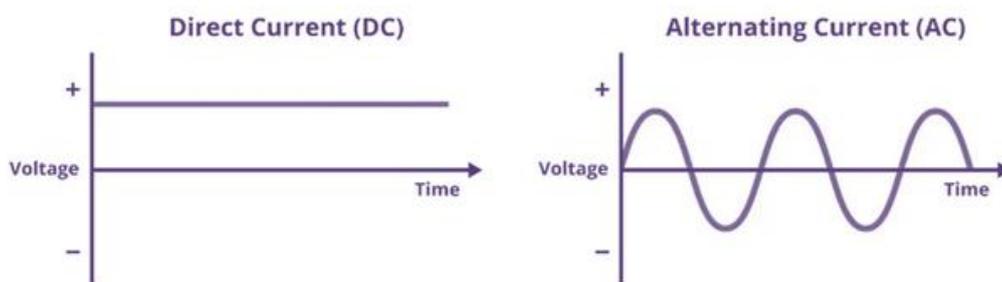
HVDC Transmission: The Backbone of Modern Power Networks

What is HVDC?

High Voltage Direct Current (HVDC) is a method of transmitting electrical power using direct current (DC) at very high voltages—typically in the range of 100 kV to 1100 kV. Unlike traditional AC transmission, where current alternates its direction 50 or 60 times per second, HVDC maintains a constant current flow, offering significant advantages for long-distance and high-capacity power transfer.

An HVDC system consists of converter stations at each end of a transmission link—one converting AC to DC (rectifier) and the other converting DC back to AC (inverter).

The DC power is transmitted through overhead lines, submarine cables, or underground cables with minimal losses compared to AC systems



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HVDC TRANSMISSION: THE BACKBONE OF MODERN POWER NETWORKS

Why is HVDC Used?

HVDC is chosen primarily for technical and economic efficiency in scenarios where AC transmission becomes impractical. Its benefits stem from the fundamental characteristics of DC power flow:

- **Lower transmission losses over long distances:** HVDC avoids reactive power flow and charging currents, reducing overall transmission losses by 30-50% compared with AC on long overhead or cable routes.
- **Requires fewer conductors:** In HVDC systems, each circuit requires only one or two conductors, whereas a three-phase HVAC circuit requires three separate conductors. As a result, HVDC uses less conductor material overall, reducing cable mass and lowering both infrastructure and installation costs.
- **Asynchronous grid interconnection:** HVDC links connect AC systems that operate at different frequencies or are not synchronized, allowing controlled energy exchange without requiring phase matching.
- **High-precision power flow control:** HVDC converters regulate active power independently of AC phase angle, stabilizing the network against disturbances due to rapid changes in power.

HVDC Converter Stations: The Heart of Modern Power Transmission and the Case for Advanced Condition Monitoring

Converter stations are the technological core of HVDC systems. Each station contains converter valves, transformers, filters, and control systems that enable conversion between AC and DC. Two main technologies are used:



1. Line-Commutated Converters (LCC-HVDC):

LCC-based HVDC systems use thyristor technology and function as current-source converters. Each converter is built from six-pulse thyristor bridges, and large installations connect multiple bridges in series to form 12-pulse or 24-pulse configurations, with each valve containing hundreds of individual thyristors.

Power flow is controlled by adjusting the firing and extinction angles of the thyristors. LCC-HVDC is well suited for very high voltages and large power ratings and is supported by a strong DC side due to the smoothing inductance connected there.

2. Voltage Source Converters (VSC-HVDC):

VSC-based HVDC systems use IGBTs, which are self-commutating and voltage-controlled devices. Their ability to switch at high frequencies allows pulse-width modulation (PWM), enabling precise and independent control of active and reactive power.

VSC systems can use different converter topologies, including 2-level, 3-level, and modular multilevel converters, and are commonly implemented in symmetrical monopole configurations.

The main components of a VSC-HVDC system include the converter transformer, which matches voltage levels, provides isolation, and supplies the needed coupling reactance; AC filters, which suppress high-frequency harmonics; and DC capacitors, which store energy and maintain a stable DC voltage. Additional elements such as DC filters, AC reactors, and DC reactors are used to reduce harmonic currents, limit fault currents, and support stable operation of the DC circuit.

Maintenance and Condition Monitoring

To keep HVDC assets reliable, continuous monitoring of corona partial discharge on transformers, bushings, insulators, conductors, and reactors is essential. OFIL's UV inspection solutions support safe and effective maintenance in environments where traditional access is limited.

- **Handheld, robotic, and fixed systems:** Handheld cameras support routine field inspections of HVDC overhead transmission lines, while robot-mounted and fixed installations are used inside HVDC converter halls and other restricted areas where personnel cannot enter during operation. These systems provide consistent, repeatable, and safe monitoring of energized equipment.
- **Automated detection:** Built-in algorithms identify corona discharge in real time, ensuring timely maintenance response.
- **Easy integration:** Systems can be integrated into existing inspection workflows, monitoring setups, and maintenance routines.

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HVDC TRANSMISSION: THE BACKBONE OF MODERN POWER NETWORKS

Gridnostic Platform:

Inspection data from handheld, robotic, and fixed systems flows into Gridnostic, where it is organized, visualized, and analyzed. The platform highlights trends, severity levels, and actionable insights, enabling maintenance teams to make informed decisions and build a data-driven asset health strategy.

**Conclusion**

HVDC technology is the backbone of the future electric grid, enabling efficient power transmission over long distances and seamless integration of renewable energy sources across continents. Its complexity demands advanced inspection and diagnostic tools to ensure long-term reliability. With OFIL's UV imaging systems and Gridnostic analysis platform, operators can maintain the health of HVDC infrastructure, safeguard investment, and ensure stable power delivery for tomorrow's interconnected energy world.

Join us at leading industry exhibitions
Discover how OFIL’s advanced inspection and diagnostic solutions are shaping the future of grid reliability.



OFIL will participate in **IR/INFO 2026**, a leading symposium for thermography and predictive maintenance professionals. Alongside our exhibition booth, we will present “**Dual-Technology Inspections: The Power of UV and IR,**” demonstrating how combined UV and IR inspections improve fault detection and reliability in electrical infrastructure through real-world case studies.



OFIL will participate in **DTECH 2026**, a premier event focused on grid resiliency, reliability, sustainability, and modernization. **Visit us at Booth UL338** to meet the OFIL team and learn how our inspection and diagnostic solutions support smarter, more reliable power networks.



OFIL will participate in **PowerTest26**, a premier electrical power conference focused on safety, workforce development, and operational excellence. **Connect with our experts at Booth 628** and discover how OFIL supports safety and reliability across power systems.



OFIL will participate in **IEEE PES T&D 2026**, a leading transmission and distribution conference and expo bringing together utilities, engineers, manufacturers, and researchers from around the world. **Visit us at Booth 4615** and explore how our inspection and diagnostic solutions support the next generation of reliable and resilient power grids.

If you would like to schedule a meeting with us at one of the exhibitions, please reach out via solution@ofilsystems.com