

# High-Voltage Direct Current Transmission (HVDC) Global Market Insights 2025, Analysis and Forecast to 2030, by Market Participants, Regions, Technology, Application

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## Abstracts

The High-Voltage Direct Current (HVDC) Transmission market is a cornerstone of modern, large-scale electrical infrastructure, representing a pivotal technology in the global energy transition. HVDC technology involves taking electric power from a three-phase Alternating Current (AC) network, converting it to DC in a converter station, transmitting it over long distances or through cables, and then converting it back to AC at the receiving end for injection into the local AC grid. This process is highly specialized and utilizes sophisticated power electronics. The core of these systems are the converter stations, which house controllable electronic switches called valves that manage the unidirectional flow of current essential for both rectification (AC to DC) and inversion (DC to AC). Complementary components, including converter transformers, filters, reactive power sources, and smoothing reactors, ensure smooth, stable, and secure operation. The market is characterized by several critical features: high barriers to entry due to the complexity and proprietary nature of converter technology; extremely long project lead times (often years) tied to national infrastructure planning; and high capital expenditure, which necessitates strong government support or long-term utility contracts. Given the International Energy Agency's (IEA) projection that electricity's share in global energy consumption will surge from 20% in 2023 to over 50% by 2050, HVDC is an indispensable technology for achieving global decarbonization and grid reliability goals. The technology itself is mature, with the first commercial link established in 1954 between mainland Sweden and the island of Gotland. The global market for HVDC Transmission equipment and projects is estimated to be valued in the range of USD 12-20 billion by 2025. Driven by accelerating investments in renewable energy integration and cross-border grid interconnectivity, the market is forecasted to

expand at a Compound Annual Growth Rate (CAGR) in the range of 3.2%-7.2% through 2030.

### Technical, Economic, Environmental, and Societal Benefits

HVDC transmission is not merely an alternative power technology but a solution that delivers significant, multi-faceted benefits across the entire power system lifecycle:

#### Technical Advantages:

Enables extremely high power transmission capacity, currently reaching up to 12 GW at  $\pm 1,100$  kV across distances exceeding 3,000 km.

Minimises power losses over long distances, making it highly efficient for bulk power transfer.

Contributes significantly to AC grid flexibility by providing independent voltage and frequency control.

Enhances grid resilience with black start capability, enabling the rapid restoration of grids after a blackout.

Allows the connection of grids with different frequencies (asynchronous grids).

Manages grid congestion more effectively through its precise control over power flow.

#### Economic Advantages:

Lowers wholesale electricity prices by facilitating the integration of diverse energy markets and cheaper generation sources.

Reduces balancing and redispatch costs due to improved control and predictability of power flow.

Offers lower operational costs over its whole life cycle owing to reduced energy losses.

Cuts infrastructure costs with narrower Rights-of-Way (RoW) for transmission

lines.

Reduces the need for intermediate substations due to fewer voltage drops over long distances.

Encourages necessary generation capacity investments by improving overall grid reliability and stability.

Environmental Advantages:

Accelerates decarbonization by reliably integrating clean energy sources such as intermittent wind and solar power, as well as remote hydro electricity.

Minimises landscape impact by reducing the transmission footprint (fewer towers and conductors).

Optimises resource use by enabling the transfer of electricity from regions with surplus generation to those with limited capacity.

Significantly lowers electromagnetic field emissions compared to AC systems.

Societal Advantages:

Increases the ability to integrate renewables, thereby enhancing public health outcomes by improving air quality.

Boosts the environmental well-being of local communities by reducing land use for transmission infrastructure.

Reduces the socio-economic impact of outages with black start capability, which ensures the rapid restoration of electricity services.

Promotes regional collaboration and energy security through cross-border energy trading and stable grid connectivity.

## Application Analysis

HVDC systems are utilized across a spectrum of critical applications, each leveraging

the technology's unique advantages in power transfer distance, capacity, and control:

**Long Distance Transmission:** This is the traditional and highest-capacity application, where HVDC minimizes power losses over distances often exceeding 1,000 km. It is vital for transporting power from large, often remote renewable energy complexes (e.g., massive solar farms in deserts, hydro plants in mountains) or ultra-supercritical power plants to distant load centers.

**Interconnecting Grid (Asynchronous Grids):** HVDC is essential for connecting neighboring AC grids that operate at different frequencies or are otherwise incompatible (asynchronous), enabling power exchange and mutual support without synchronization issues, thereby enhancing regional energy security.

**City Centre Infeed (Cable Links):** Due to the high reactive power limitations of long AC cables, HVDC is the superior solution for transmitting bulk power into densely populated urban centers using underground or submarine cables, minimizing land usage and visual impact.

**Offshore Renewable Energy:** This is one of the fastest-growing segments. HVDC is the most technically and economically viable method for collecting power from large-scale offshore wind farms and transmitting it back to the onshore AC grid, often over tens or hundreds of kilometers of submarine cable. The technology's control features are crucial for managing the intermittent nature of wind power.

**Others:** This includes specialized applications like supplying power to remote industrial loads, mining operations, or oil/gas platforms where laying long AC lines is impractical or too costly.

## Regional Market Trends

The global HVDC market exhibits a highly asymmetrical distribution of installed capacity, reflecting large-scale national infrastructure policies and resource availability.

**Asia-Pacific (APAC):** APAC is the dominant global market and the primary driver of new capacity, holding an Installed Capacity share of over 65% in 2024.

China holds an absolute dominant market share, accounting for over

55% of the global installed capacity. This massive scale is driven by China's national strategy to transmit huge amounts of hydroelectric and ultra-high-voltage (UHV) power from remote western regions to high-demand eastern megacities, necessitating the deployment of the world's highest-voltage UHVDC projects. The focus remains on domestic projects and expanding UHV capacity.

Other countries in the region are increasingly investing in HVDC for cross-border interconnectors and integrating utility-scale solar and wind projects. The region is forecasted to grow at a high CAGR in the range of 4.5%-8.5% through 2030, sustained by aggressive infrastructure build-out.

**Europe:** Europe represents the second-largest HVDC market, with an Installed Capacity share of approximately 15% in 2024.

Growth in Europe is primarily driven by the imperative to decarbonize its energy mix by connecting national grids (Interconnecting Grid) and integrating offshore wind energy (Offshore Renewable Energy). Key markets like the UK, Germany, and the Nordic countries are continuously investing in submarine cable links to create a unified energy market and maximize the use of renewable resources.

The region's market is projected to expand at a robust CAGR in the range of 3.5%-7.5% through 2030, supported by EU-level policy mandates for cross-border energy infrastructure.

**North America:** North America is the third-largest market, with an Installed Capacity share of approximately 8% in 2024.

The US and Canada are focused on utilizing HVDC for Long Distance Transmission, often to bring remote renewable power (e.g., large hydro or wind farms) to population centers. Investment is steady, driven by grid modernization efforts and regulatory approval processes for large interstate transmission projects.

The region's CAGR is estimated in the range of 2.0%-6.0% through 2030, dependent on the acceleration of large-scale green energy corridor projects and cross-regional grid strengthening.

**Latin America and Middle East & Africa (MEA):** These regions show moderate

but important growth, with a forecasted CAGR in the range of 2.5%-6.5% through 2030. Latin America, particularly Brazil, uses HVDC to move power from large hydro complexes to distant industrial centers. MEA's growth is spurred by large-scale solar projects and regional grid synchronization efforts in the Gulf countries and key African markets.

## Company Profiles

The HVDC market is dominated by a few global engineering conglomerates with deep technical expertise, proprietary converter technology, and the necessary manufacturing scale for large-scale electrical infrastructure.

**Siemens Energy:** A global powerhouse in energy technology, Siemens Energy is a key leader in the HVDC market, providing advanced converter systems (both Line-Commutated Converter - LCC and Voltage Source Converter - VSC technologies) and comprehensive turnkey solutions for utility customers worldwide. The company is heavily involved in high-capacity projects and grid modernization efforts across Europe and the Americas.

**Hitachi Energy Ltd:** Emerging from the acquisition of ABB's power grids business, Hitachi Energy is recognized as a leader in HVDC systems, boasting a vast installed base and proprietary VSC technology (HVDC Light). The company focuses on challenging applications like offshore wind integration and long-distance interconnectors, leveraging its deep experience in both classic and VSC HVDC solutions.

**GE Vernova:** As a global energy transition leader, GE Vernova provides advanced power transmission solutions, including HVDC systems. The company competes across various applications, with a strong focus on high-voltage components and providing integrated solutions that enhance grid reliability and resilience for utilities.

**Mitsubishi Electric:** A major Japanese industrial and electrical equipment manufacturer, Mitsubishi Electric is a significant player, particularly in the APAC region and in specialized applications. The company is known for its high-quality converter valves and commitment to innovation in HVDC technology for enhancing Japan's grid stability and international projects.

## Industry Value Chain Analysis

The HVDC value chain is a long, complex sequence dominated by engineering, manufacturing precision, and installation expertise.

**Upstream: Component Manufacturing:** The value chain starts with the high-specification production of critical components:

**Valves:** The core of the converter, requiring specialized, high-power semiconductor technology (e.g., Thyristors for LCC, IGBTs for VSC) that must withstand extreme voltages.

**Converter Transformers:** Massive, customized transformers designed for DC systems.

**Cables/Lines:** Manufacturing of specialized high-voltage DC cables (both terrestrial and submarine) or specialized conductors for overhead lines.

Supply is consolidated and requires high precision, often featuring captive or heavily qualified suppliers.

**Midstream: System Design and Converter Station Integration:** This is the high-value phase where the HVDC leaders (Siemens, Hitachi, GE) perform:

**Advanced Engineering:** Detailed system studies, power flow modeling, and customized station design to ensure compatibility with the receiving AC grid.

**Converter Manufacturing:** Assembly and rigorous testing of the complex converter hall equipment, including valves, control systems, and cooling systems.

This phase involves immense project management and technical risk mitigation.

**Downstream: Project Execution, Commissioning, and Service:**

**Construction and Installation:** Executing the massive civil works, laying cables, and erecting converter stations, often in remote or offshore

locations.

**Commissioning:** The highly specialized process of integrating and testing the new HVDC system with the existing AC grid.

**Aftermarket Services:** The most stable revenue stream, involving long-term maintenance contracts, spare parts supply, digital monitoring services, and system upgrades (modernizing valves or control systems).

## Opportunities and Challenges

The HVDC market stands to benefit profoundly from the global energy transition but must navigate significant project and regulatory obstacles.

### Opportunities

**Global Decarbonization Push:** HVDC is the crucial link for integrating vast, often remote, renewable energy sources (wind, solar, hydro) into existing grids, making it essential for virtually every country's net-zero transition plan.

**Offshore Grid Development:** The massive planned expansion of offshore wind, particularly in Europe and Asia, necessitates large-scale VSC-HVDC grids and multi-terminal configurations, unlocking significant new project volumes.

**Intercontinental and Regional Grid Interconnectors:** Growing political and economic imperatives for energy security and trading will drive demand for new cross-border HVDC interconnectors, especially between continents (e.g., Africa-Europe, Asia interconnectors).

**Grid Modernization and Resilience:** The ability of HVDC to enhance AC grid stability, provide black start capability, and control power flow precisely makes it indispensable for modernizing and hardening existing, aging transmission infrastructure.

### Challenges

**High Capital Expenditure and Project Risk:** HVDC projects require massive

upfront investment and carry significant risk due to their scale, complexity, and long, multi-year construction timelines, often requiring complex financial and governmental guarantees.

**Regulatory and Permitting Hurdles:** Securing permits and rights-of-way for long-distance transmission lines or submarine cables, often spanning multiple jurisdictions and sensitive environmental areas, can cause lengthy delays and increase project costs significantly.

**Technology Standardization:** The lack of fully standardized VSC technologies, especially for multi-terminal DC grids, limits vendor interoperability and increases integration complexity, although industry efforts are working to address this.

**Talent and Expertise Shortages:** The specialized nature of HVDC system design, manufacturing, and field service creates a global shortage of highly skilled engineers and technicians, which can constrain the pace of project execution.

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