

HVDC Transmission

Industry Primer

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The Direct Route: How HVDC Became the Enabling Technology for the Global Energy Transition

1. Opening Thesis and Structural Argument

The global high voltage direct current (HVDC) transmission industry sits at the precise center of the renewable energy transition, with demand being pulled by policy mandates for 7,000 GW of renewable capacity by 2030 and constrained by a supply chain where three companies control 70 to 80% of converter stations and European manufacturers hold two-thirds of global cable capacity. The structural imbalance between demand and supply has created a seller's market where converter station lead times stretch 24 to 36 months and tender prices have increased 2.5 times over the last five years.

The HVDC transmission market is valued at USD 15.62 billion in 2025 and is projected to reach USD 22.07 billion by 2030, representing a compound annual growth rate of 7.2%. The converter station segment alone reached USD 13.68 billion in 2024 according to Fortune Business Insights and is projected to nearly double to USD 30.41 billion by 2032 at a 10.5% compound annual growth rate. The HVDC cables market exceeded USD 9.6 billion in 2024 and is expected to grow at 24.3% compound annual growth rate from 2025 to 2034, reflecting the acute binding constraint in submarine cable supply.

I see three structural drivers creating a decade of sustained demand growth. First, renewable energy integration mandates require long-distance transmission to connect remote solar and wind resources to demand centers. India's 500 gigawatt renewable target by 2030, the European Union's 42.5% renewable energy target under REPowerEU, and China's 1,200 gigawatt wind and solar target collectively require transmission infrastructure that can efficiently move bulk power over distances exceeding 600 kilometers. HVDC is the only technology that can transmit power over such distances with losses below 3%.

Second, offshore wind development requires HVDC export cables for each major project. The North Sea alone is targeting 65 gigawatts of offshore wind by 2030, up from 20 gigawatts currently, requiring a massive expansion of HVDC infrastructure. TenneT's 2 gigawatt Program, which builds eight Dutch and three German offshore grid connection systems, represents EUR 23 billion in HVDC contracts awarded in 2023.

Third, data center power demand is emerging as an unexpected demand driver. Artificial intelligence and cloud computing are driving electricity consumption that could reach 945 terawatt hours globally by 2030, doubling from current levels. AI data centers could consume 9% of US electricity by 2030, triple current usage, requiring transmission infrastructure to deliver reliable high-capacity power to hyperscale facilities.

The companies that control converter stations and submarine cables will capture a decade of structurally higher growth. Hitachi Energy has integrated over 150 gigawatts of HVDC capacity globally, more than any competitor, with its proprietary MACH control system creating switching costs that no competitor can replicate. Prysmian Group, the world's largest cable manufacturer, owns four cable-laying vessels and has confirmed that transmission capacity is fully sold out through 2029 with a backlog of EUR 14 to 16 billion. Siemens Energy and GE Vernova are expanding manufacturing capacity in Europe and North America to capture the structural wave of demand.

The supply side tells a story of concentration and constraint. The top three converter station original equipment manufacturers (Hitachi Energy, Siemens Energy, GE Vernova) control an estimated 70 to 80% of the non-Chinese market. European cable manufacturers (Prysmian, Nexans, NKT) represent approximately two-thirds of global HVDC cable manufacturing capacity according to the International Energy Agency. China's domestic market is served by NR Electric and State Grid equipment manufacturers, with limited export visibility.

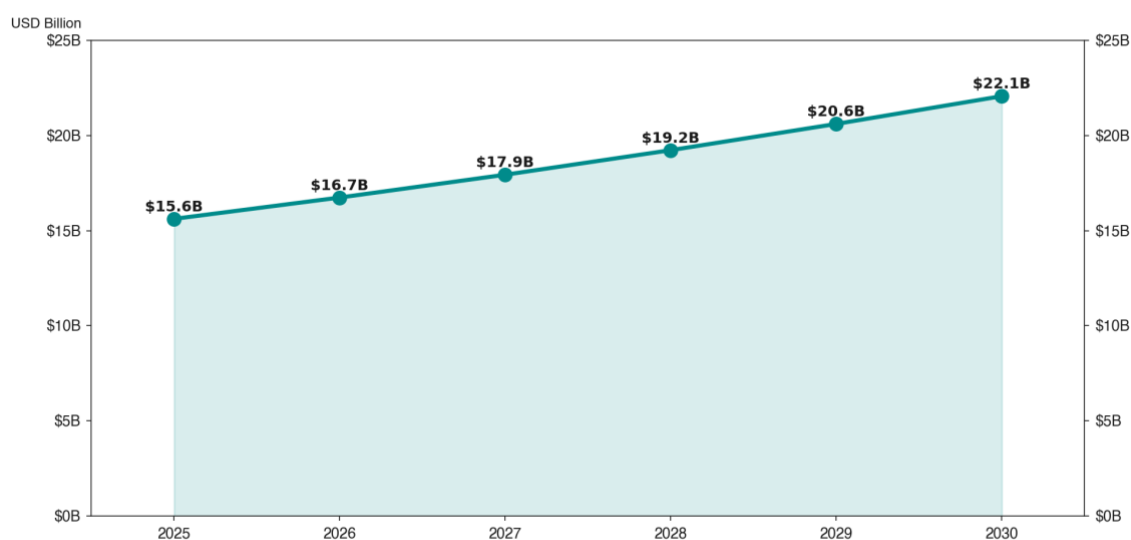
The technology transition from Line Commutated Converter (LCC) to Voltage Source Converter (VSC) systems is creating a second dimension of differentiation. VSC technology, which enables black-start capability, independent reactive power control, and smaller station footprint, is gaining market share for

offshore wind and multi-terminal applications. Hitachi Energy and Siemens Energy have positioned their portfolios toward VSC, while legacy LCC continues to dominate China's ultra-high voltage direct current (UHVDC) backbone network.

India represents the fastest-growing HVDC market globally, with a compound annual growth rate of 8.65% and a market size expected to reach USD 3.86 billion in 2025. The Bhadla-Fatehpur 6 gigawatt HVDC link, awarded to the Hitachi Energy-BHEL consortium in April 2025, will transmit renewable energy 950 kilometers from the Bhadla solar park in Rajasthan to Fatehpur in Uttar Pradesh, powering approximately 50 million households. The localization push under Make in India creates a structural opportunity for Indian equipment manufacturers like BHEL, GE Vernova T&D India, Quality Power, and Transformers and Rectifiers India (TARIL) to capture domestic value while partnering with global technology leaders.

I believe the HVDC industry is in a structural expansion phase, not a cyclical upswing. The policy commitments through COP28, REPowerEU, the US Inflation Reduction Act, and India's 500 gigawatt target have locked in demand through 2030. Supply chain constraints in cable vessels and converter engineering capacity create multi-year backlogs and pricing power for incumbents. The companies that own the bottlenecks will capture the value.

CHART 1
Global HVDC Transmission Market Size (2025-2030)



SOURCE: MARKETANDMARKETS, FINANCEPULSE

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2. Demand Landscape: Policy, Grids, and the Renewable Imperative

The demand for HVDC transmission is structural, driven by policy mandates that have committed major economies to aggressive renewable energy targets through 2030 and beyond. The COP28 tripling pledge saw 133 countries commit to tripling global renewable capacity by 2030, establishing a demand floor that transcends economic cycles. Global renewable capacity targets now exceed 7,000 gigawatts by 2030, up from approximately 3,800 gigawatts in 2023.

Renewable Integration Mandates

HVDC is the enabling technology for renewable integration because it is the only viable method for efficiently transmitting bulk renewable power over distances exceeding 600 kilometers with losses below 3%. Solar and wind resources are often located far from demand centers, requiring transmission infrastructure that can move gigawatts of power across continents or under seas.

India's 500 gigawatt non-fossil fuel capacity target by 2030, up from approximately 180 gigawatts in 2024, represents one of the world's most aggressive renewable expansion programs. The Central Electricity Authority estimates that Rs 2.44 lakh crore (approximately USD 30 billion) is needed for Inter-State Transmission System infrastructure to support the 500 gigawatt target. The transmission investment required includes Rs 2.16 lakh crore for 268 gigawatts of onshore renewable energy evacuation and Rs 28,100 crore for 10 gigawatts of offshore wind energy transmission infrastructure.

The Green Energy Corridors initiative, designed to evacuate renewable power from resource-rich states to demand centers, has been approved in two phases. Phase I targeted evacuation of approximately 20 gigawatts. Phase II, approved by the Cabinet in 2022, targets an additional 20 gigawatts of renewable energy capacity evacuation. The structural lag between renewable installations and evacuation capacity has left approximately 40 gigawatts of renewable capacity stuck due to lack of transmission infrastructure or power purchase agreements, according to Moneycontrol reporting from February 2026.

The European Union has set a 42.5% renewable energy target by 2030 under REPowerEU, requiring massive expansion of both onshore and offshore transmission infrastructure. The United States has committed to 50 to 52% emissions reduction by 2030 from 2005 levels, with the Inflation Reduction Act catalyzing domestic transmission investment. China has already achieved 1,000 gigawatts of wind and solar capacity by 2024, targeting 1,200 gigawatts by 2030.

Offshore Wind Transmission

Offshore wind farms located 50 to 150 kilometers from shore require HVDC transmission for efficient power delivery. HVAC transmission becomes uneconomical beyond approximately 80 kilometers due to reactive power losses and cable capacitance issues, making HVDC the only viable solution for the next generation of offshore wind projects.

The North Sea offshore wind target is 65 gigawatts by 2030, up from 20 gigawatts currently, according to GE Vernova. The European Union has set a target of at least 60 gigawatts of offshore wind by 2030 and 300 gigawatts by 2050. TenneT's 2 gigawatt Program represents the world's largest offshore wind grid connection initiative, building eight Dutch and three German offshore grid connection systems with total transmission capacity equivalent to 22 power plants.

TenneT awarded EUR 23 billion in HVDC contracts in 2023 for Dutch and German North Sea grid connections, representing the single largest commitment to HVDC infrastructure in the industry's history. The program demonstrates the scale of investment required to connect offshore wind to continental grids.

The UK has set a 50 gigawatt offshore wind target by 2030, requiring significant HVDC infrastructure expansion. The United States has a 30 gigawatt by 2030 target, with an Atlantic coast HVDC backbone under planning. India has identified 10 gigawatts of offshore wind potential by 2030, with Gujarat and Tamil Nadu as key zones.

The ENTSO-E Ten-Year Network Development Plan 2024 tested 141 transmission projects and 23 storage projects against 2030 and 2040 scenarios. Major HVDC interconnector projects include the Green Aegean Interconnector (Germany-Greece, EUR 8.1 billion), the Baltic WindConnector (Germany-Estonia, EUR 6.6 billion), and HansaLink Phase 1 (Germany-UK, EUR 5.26 billion). These projects represent cumulative HVDC demand from submarine interconnectors of EUR 86 billion by 2032, or 53% of all HVDC demand.

"In terms of the transmission, TSOs have to digest the wave of order and the significant surge in order intake orders that they sent to the market in '23. So we don't see a slowdown in itself. We see that for the next 5 years, we are flat out in transmission." -- Massimo Battaini, CEO, Prysmian Group, Q4 2025 Earnings Call

Data Center Power Demand

Artificial intelligence and cloud computing are driving unprecedented electricity demand growth from data centers, creating a structural demand driver that was not anticipated in the previous decade. US data centers consumed 4% of total US electricity in 2024 according to Pew Research. Global data center electricity demand is projected to reach 945 terawatt hours by 2030, doubling from current levels according to the International Energy Agency.

AI could drive a 165% increase in data center power demand by 2030. AI data centers could consume 9% of US electricity by 2030, triple current usage. The US and China will account for 80% of projected data center electricity demand growth.

Grid spending of approximately USD 720 billion through 2030 may be needed to support data center growth. Grid constraints are already limiting data center development in key markets like Northern Virginia and Dublin, creating near-term pressure for transmission solutions. HVDC is emerging as a candidate technology for long-distance supply to hyperscale facilities.

"In data center space, we've seen our revenues 9 months to date versus 9 months last year, doubling in value." -- Massimo Battaini, CEO, Prysmian Group, Q3 2025 Earnings Call

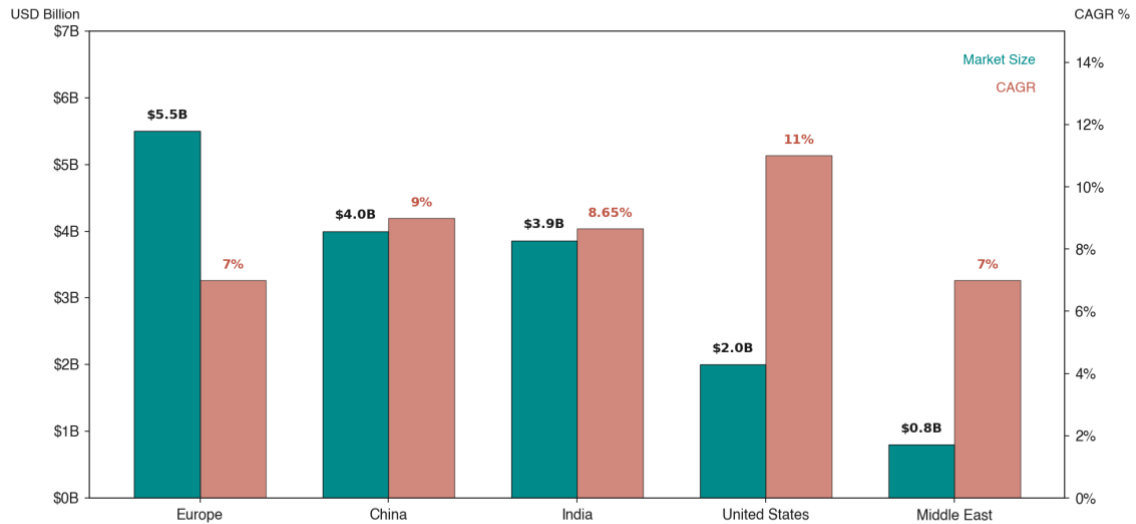
Cross-Border Interconnections

Countries are investing in cross-border HVDC interconnectors to improve grid resilience, access cheaper power, and integrate geographically diverse renewable resources. The European cross-border interconnection target is 15% of installed capacity by 2030.

UK-Continental Europe interconnectors have over 10 gigawatts of HVDC capacity operational or under development. The Viking Link, a 1.4 gigawatt UK-Denmark interconnector, demonstrates the technology for cross-border trade. Asia-Pacific interconnections are growing through interest in an ASEAN power grid and Northeast Asia interconnections.

India has operational cross-border infrastructure including the 1.6 gigawatt HVDC back-to-back link with Bangladesh and multiple cross-border lines with Nepal under development. Undersea cable feasibility with Sri Lanka is being explored, representing a future HVDC opportunity.

CHART 3
HVDC Market by Region (2025 Size vs Growth Rate)



SOURCE: MARKETSSANDMARKETS, MORDOR INTELLIGENCE, FINANCEPULSE

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Demand by Geography and Segment

Region	Market Size (2025)	Growth Rate	Key Dynamics
Europe	~USD 5.5 billion	6-8% CAGR	Offshore wind backbone, cross-border integration, decarbonization policy
China	~USD 4 billion	8-10% CAGR	UHVDC backbone expansion, renewable integration, domestic manufacturing
India	USD 3.86 billion	8.65% CAGR	Green Energy Corridors, 500 GW renewable target, localization push
United States	~USD 2 billion	10-12% CAGR	Grid modernization, data center demand, offshore wind emerging
Middle East	~USD 0.8 billion	6-8% CAGR	GCC interconnections, solar integration, industrial demand

The HVDC demand by segment reflects the structural drivers. Renewable integration represents approximately USD 6.5 billion, growing at 9% compound annual growth rate. Offshore wind export is USD 4.0 billion, growing at 12% compound annual growth rate as North Sea projects accelerate. Interconnection represents USD 2.5 billion at 7% compound annual growth rate. Industrial and mining applications, including data centers, represent USD 1.5 billion at 5% compound annual growth rate.

Scope note on offshore wind and regional pipeline figures: The offshore wind demand figures cited above derive from European TSO projections (TenneT, ENTSO-E TYNDP 2024) and company guidance. These figures represent committed or planned capacity, not all of which has secured HVDC equipment contracts. The regional project pipeline figures for Europe (65 GW by 2030), US (30 GW by 2030), and India (10 GW potential by 2030) are policy targets from respective government bodies. When geographic coverage overlaps, such as UK projects counted in both European Union aggregate figures and UK-specific targets, the regional pipeline figures should be understood as policy commitments by jurisdiction, not additive global totals. The global HVDC market sizing (USD 15.62 billion in 2025) from MarketsandMarkets

represents the addressable market for HVDC transmission systems including converters, cables, and controls, and is the anchor figure for market-level analysis.

3. Supply Dynamics: Concentration, Constraints, and Manufacturing Bottlenecks

The HVDC supply chain is characterized by extreme concentration at multiple tiers, creating structural bottlenecks that constrain the pace of global transmission buildout. The supply side is the binding constraint on industry growth, with demand outpacing manufacturing capacity and engineering expertise by a significant margin.

Converter Station Concentration

The HVDC converter station market was valued at USD 13.68 billion in 2024 and is projected to reach USD 30.41 billion by 2032 at a 10.5% compound annual growth rate. This growth rate significantly exceeds current manufacturing capacity expansion rates, creating a structural supply deficit.

The converter station market is effectively a three-player oligopoly plus one Chinese firm. Hitachi Energy, Siemens Energy, and GE Vernova manufacture over 90% of HVDC converters globally outside China, with NR Electric dominant within China. This concentration has developed through decades of industry consolidation. ABB sold its Power Grids business to Hitachi in 2020, transforming into Hitachi Energy. Alstom Grid was acquired by GE, now operating as GE Vernova Grid Solutions.

Converter station lead times have extended from historical norms of 18 to 24 months to 24 to 36 months currently. HVDC converter wait time in Europe extends to almost 10 years as of late 2025 according to industry research, reflecting the extreme supply-demand imbalance. HVDC tender prices have increased 2.5 times over the last five years.

The installed base of qualified HVDC power electronics engineers represents a binding constraint. Major original equipment manufacturers report challenges in scaling engineering teams quickly enough to meet project pipeline demand. Engineering expertise requires 5 to 10 years to develop, limiting the pace at which capacity can expand.

"\$6 billion investment capital expenditure has been decided and is carried out... The current order and capacity is at high level. So we have decided to make further investments in capacity to meet the demand." -- Toshiaki Tokunaga, CEO, Hitachi Energy parent, Q4 FY2024 Earnings Call

Siemens, Hitachi, and GE Vernova have announced more than USD 3 billion globally to expand HVDC facilities in anticipation of demand. GE Vernova is expanding manufacturing facilities in Stafford, UK, focusing on grid solutions and HVDC equipment. The company won a contract with Seatrium in December 2025 to deliver a major part of BalWin5, a 2.2 gigawatt HVDC offshore wind transmission system in the German North Sea.

Cable Manufacturing Concentration

European manufacturers (Prysmian, Nexans, NKT) represent approximately two-thirds of global HVDC cable manufacturing capacity according to the International Energy Agency. This concentration creates supply chain vulnerability for regions without local manufacturing capacity.

The HVDC cables market exceeded USD 9.6 billion in 2024 and is expected to grow at 24.3% compound annual growth rate from 2025 to 2034. Demand for offshore power cables is projected to increase five-fold by 2030 relative to 2020 levels. High-voltage cable demand is forecast to grow at a 16% compound annual growth rate over 2020 to 2030, with an average market size of EUR 17.9 billion per year over 2025 to 2030, significantly outpacing supply growth at 8% compound annual growth rate.

Prysmian holds approximately 17% market share of the high-voltage cables market. NKT holds approximately 12%. Nexans holds approximately 9%. The sector backlog is expected to grow at a 14%

compound annual growth rate from EUR 38.5 billion in 2024 to EUR 86.7 billion by 2030, enhancing cable makers' pricing power beyond 2030.

"Our capacity is fully sold out through 2029. So a level of backlog between EUR 14 billion and EUR 16 billion is what we recognize more healthy to be competitive in terms of flexibility to work and respond to the new project intake." -- Massimo Battaini, CEO, Prysmian Group, Q2 2025 Earnings Call

The Prysmian transmission backlog is sufficient to fully utilize plant capacity until at least 2029. NKT capacity appears close to fully utilized. Nexans is approximately 83% utilized on average over 2025 to 2029 according to industry research. The margin trajectory for high-voltage cables is expected to track higher toward 2030 as better-priced orders flow through cable makers' income statements with a multi-year lag.

Cable Vessel Availability: The Binding Constraint

Cable-laying vessel availability is the binding constraint for offshore HVDC projects. Between 2020 and 2028, the amount of cable laid is projected to increase 9.5-fold, from 1,932 kilometers to 18,173 kilometers, requiring proportional increases in cable-laying vessel capacity. New vessels ordered today will not join the fleet until 2026 to 2027, with lead times of 3 to 5 years.

Prysmian owns four cable-laying vessels (Leonardo da Vinci, Cable Enterprise, Giulio Verne, Mon Repos), providing preferential access to the constrained installation market. Nexans also owns or operates vessels. NKT has limited vessel ownership, creating execution risk in the constrained installation market. The ownership of vessels provides a competitive moat that extends beyond manufacturing capacity.

New cable manufacturing capacity is being built in the UK to support North Sea offshore wind. Sumitomo Electric's Nigg facility, JDR's Cambois facility, and XLCC's Hunterston facility are all under development, but capacity remains tight through 2027.

Semiconductor Supply Concentration

High-power semiconductors for HVDC valves represent the most concentrated input in the value chain. Infineon Technologies is a leading supplier of HVDC thyristors, with Mitsubishi Electric, Hitachi, and Toshiba as secondary sources. The IGBT market for VSC-HVDC applications is similarly concentrated.

Semiconductor procurement for major HVDC projects now requires 12 to 18 month advance ordering, up from 6 to 12 months historically. The concentration creates supply chain risk, though original equipment manufacturers maintain strategic semiconductor inventories.

Geographic Distribution of Supply

Region	% of Global Supply	Key Players	Trend
Europe (Cables)	~65%	Prysmian, Nexans, NKT	Capacity expansion underway
Europe (Converters)	~40% (ex-China)	Hitachi Energy, Siemens Energy	Strong but capacity-constrained
China (Converters)	~35% global	NR Electric, State Grid manufacturers	Dominant domestically
Japan (Converters)	~10%	Toshiba, Mitsubishi Electric	Stable
US (Converters)	~10%	GE Vernova	Expanding
India (Transformers)	Growing	BHEL, TARIL, TELK	Localization push

China operates more than 50 HVDC lines including the world's highest voltage ± 1100 kilovolt UHVDC systems. Chinese domestic manufacturers, primarily subsidiaries of State Grid Corporation, supply the vast majority of equipment for the domestic market. NR Electric, a subsidiary of NARI Group, is China's leading HVDC control and protection supplier with its PCS-9000 series platform.

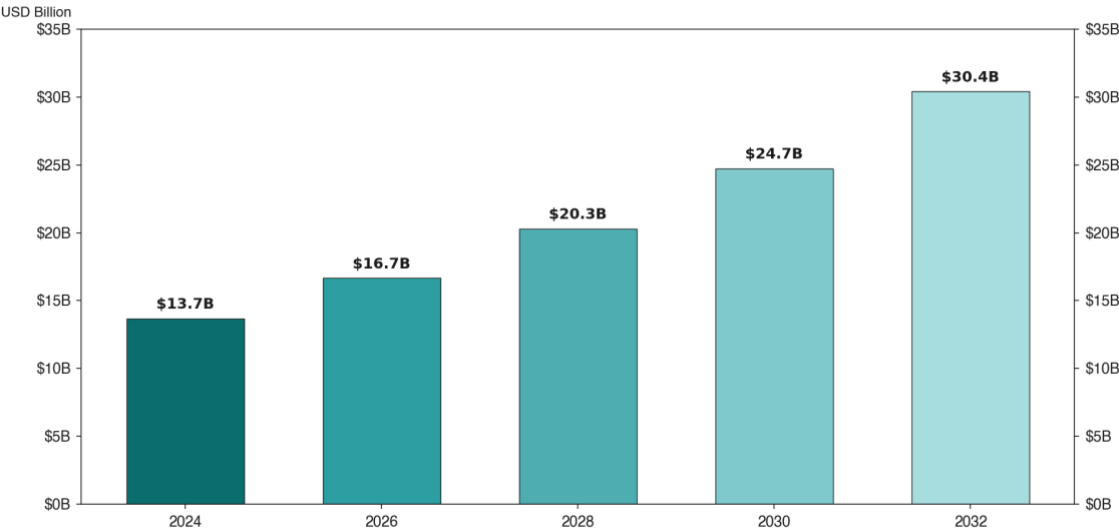
Utility Qualification Requirements

HVDC converter stations require extensive reference track records with major transmission system operators. New entrants must demonstrate multiple successful projects with utilities like TenneT, National Grid, or POWERGRID before being considered for major tenders. This creates a multi-year barrier to market entry that protects incumbents.

Each national grid has specific requirements for HVDC system behavior under fault conditions, frequency response, and reactive power capability. Meeting these requirements demands deep local knowledge and extensive testing. Full type testing and qualification for a new HVDC converter design typically requires 18 to 24 months.

The Netherlands has categorized HVDC as critical infrastructure and has limited participation to European firms, reflecting growing national security concerns around high-power grid infrastructure. Chinese firms may find it increasingly difficult to compete in European HVDC markets due to such national security concerns.

CHART 2
HVDC Converter Station Market (CAGR 10.5%)



SOURCE: FORTUNE BUSINESS INSIGHTS, FINANCEPULSE

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4. Value Chain Deep Dive: Tier by Tier from Semiconductors to Grid Operators

The HVDC transmission value chain is organized as a tiered stack from end customers at the top through converter station original equipment manufacturers, cable manufacturers, component suppliers, and power semiconductor providers at the base. The defining characteristic is extreme concentration at multiple tiers, creating structural bottlenecks that constrain global transmission buildout.

Tier 6: Power Semiconductors (Thyristors, IGBTs)

Power semiconductors manufacture high-power semiconductor devices used in HVDC converter valves. Thyristors dominate Line Commutated Converter systems, while Insulated Gate Bipolar Transistors are used in Voltage Source Converter systems.

The global IGBT and thyristor market was valued at approximately USD 60.21 billion in 2024, projected to reach USD 105.81 billion by 2034. The HVDC-specific segment is a subset of this broader market.

Key players: Infineon Technologies (IFX.DE, Germany) is the leading supplier of HVDC thyristors. Mitsubishi Electric (6503.T, Japan), Hitachi (6501.T, Japan), and Toshiba (6502.T, Japan) are secondary sources. CRRC (1766.HK, China) has domestic semiconductor capability.

Concentration: High. Top 4 players control approximately 70% of HVDC semiconductor supply.

Entry barriers: Very high. Requires advanced semiconductor fabrication capability, long-term reliability testing under extreme electrical stress, and qualification with converter original equipment manufacturers spanning multiple years. Capital requirements exceed USD 1 billion for fabrication facilities.

India participation: Near zero. India has no domestic manufacturing of high-power thyristors or IGBTs for HVDC applications. Complete import dependency represents a critical vulnerability in India's localization strategy.

Tier 5: Control and Protection Systems

Control and protection systems provide the algorithms, protection relays, and automation systems that govern HVDC converter operation, including power flow control, fault response, and grid integration functions.

Market size: Control and protection systems represent approximately 10 to 15% of converter station value, implying a market size of approximately USD 1.2 to 1.8 billion annually.

Key players: Hitachi Energy (MACH control system) with over 150 gigawatts integrated globally. NR Electric (PCS-9000 series) dominant in China. Siemens Energy and GE Vernova have integrated control platforms.

Concentration: Very high. Control systems are deeply integrated with original equipment manufacturer converter offerings and are not interchangeable between vendors. Hitachi Energy's MACH system is a proprietary platform that locks customers into Hitachi technology for upgrades and lifecycle support.

Entry barriers: Extremely high. Control algorithms are proprietary and represent decades of research and development investment. New entrants would need to demonstrate multi-year operational track record, navigate complex grid code compliance across multiple jurisdictions, and build simulation and testing infrastructure. The embedded base of installed systems creates switching costs for utilities.

India participation: Very low (estimated 20% localization). India lacks domestic capability for HVDC control and protection systems. These remain proprietary to global original equipment manufacturers.

Tier 4: Reactors, Filters, and Auxiliary Equipment

Reactor and filter manufacturers provide smoothing reactors, AC/DC filters, surge arresters, cooling systems, and auxiliary systems that support converter station operation. Smoothing reactors limit DC ripple current and protect valves from transient overvoltages.

Market size: The global HVDC smoothing reactor market reached approximately USD 1.54 billion in 2024. Combined with filters and other auxiliary equipment, this tier represents approximately 10 to 15% of converter station value.

Key players: Hitachi Energy and Siemens Energy manufacture reactors and filters in-house. Quality Power Electrical Equipments (QPOWER.NS, India) is an emerging HVDC reactor specialist with Rs 34 crore in domestic orders. CG Power and Industrial Solutions (CGPOWER.NS, India) has reactor and transformer capability.

Concentration: Moderate to fragmented. Original equipment manufacturers often manufacture reactors and filters in-house, but specialized regional suppliers also participate.

Entry barriers: Medium. Technical requirements are stringent (harmonic current handling, thermal management, partial discharge limits) but manufacturing processes are more accessible than for converter valves or controls.

India participation: Moderate to high (estimated 60% localization). Indian companies have established HVDC reactor manufacturing capability. Quality Power has won Rs 34 crore in domestic HVDC reactor orders. This represents one of the areas where India has made meaningful localization progress.

Tier 3: Converter Transformers

Converter transformer manufacturers produce specialized transformers that connect AC grids to HVDC converter stations. Converter transformers must handle harmonic currents, withstand DC voltage stress, and provide the voltage transformation between AC grid and DC link.

Market size: The global HVDC converter transformers market is projected to reach USD 12.5 billion by 2033, growing at 7.8% compound annual growth rate from 2025.

Key players: Hitachi Energy has a global transformer manufacturing footprint. Siemens Energy has European manufacturing. GE Vernova/Prolec GE has a global footprint including Mexico. BHEL (BHEL.NS, India) is India's largest power equipment manufacturer with HVDC converter transformer capability. Transformers and Rectifiers India (TARIL.NS) won a Rs 53 crore HVDC converter transformer order. TELK (private, India) has HVDC capability.

Concentration: Moderate globally, but higher for HVDC-specific capability. The global transformer market is fragmented, but HVDC converter transformer capability requires specialized design expertise, testing facilities, and track record with HVDC projects.

Entry barriers: High. Requires ultra-high voltage testing facilities, specialized design expertise for harmonics and thermal management, and reference track record with major utilities. BHEL developed India's first 1200 kilovolt ultra-high voltage transformer in-house in February 2026, demonstrating growing capability.

India participation: High (estimated 70% localization). India has developed strong converter transformer manufacturing capability through BHEL, TARIL, and TELK. BHEL's partnership with Hitachi Energy on the Bhadla-Fatehpur 6 gigawatt HVDC project demonstrates the capability. This is one of the most successfully localized tiers of the HVDC value chain in India.

Tier 2: HVDC Cables

HVDC cable manufacturers produce and install submarine and underground HVDC cables for power transmission. Submarine cables are critical for offshore wind export and cross-border interconnections.

Market size: The HVDC cables market exceeded USD 9.6 billion in 2024 and is expected to grow at 24.3% compound annual growth rate from 2025 to 2034. The market is expected to reach USD 13.40 billion in 2025 and USD 17.10 billion by 2030.

Key players: Prysmian Group (PRY.MI, Italy) is the world's largest cable manufacturer with dominant HVDC submarine cable position and EUR 19.6 billion revenue. Nexans (NEX.PA, France) is the second-largest European HVDC cable manufacturer with EUR 7.2 billion revenue. NKT (NKT.CO, Denmark) is a specialized HVDC cable manufacturer with EUR 3.2 billion revenue. Sumitomo Electric (5802.T, Japan) has the A-Nord 525 kilovolt project in Germany and a UK factory under construction. LS Cable (006260.KS, Korea) has regional capability.

Concentration: High. Top 5 companies control approximately 30% of the HVDC cables market. European manufacturers represent approximately two-thirds of global HVDC cable manufacturing capacity.

Entry barriers: Very high. Requires specialized manufacturing facilities for cross-linked polyethylene insulation, high-voltage testing infrastructure, and installation vessel capability. Cable-laying vessel availability is a binding constraint with 3 to 5 year lead times for new vessels.

India participation: Very low (estimated 15% localization). India has limited domestic capability for submarine HVDC cable manufacturing. Major offshore projects would require imports from European or Asian manufacturers. This represents a significant gap in India's localization strategy.

Tier 1: Converter Station OEMs (System Integrators)

Converter station original equipment manufacturers design, supply, and commission complete HVDC converter stations including valves, transformers, reactors, filters, control systems, and civil works. They act as system integrators coordinating multiple component suppliers.

Market size: The global HVDC converter station market was valued at USD 12.17 billion in 2024, projected to reach USD 15.84 billion by 2030 at 4.8% compound annual growth rate. Alternative estimates place the market at USD 13.68 billion in 2024, growing to USD 30.41 billion by 2032 at 10.5% compound annual growth rate.

Key players: Hitachi Energy (HTHIY, Switzerland/Japan) is the global market leader with estimated 30 to 35% of non-Chinese market share. Siemens Energy (ENR.DE, Germany) holds 20 to 25% market share. GE Vernova (GEV.NYSE, US) holds 15 to 20% market share. NR Electric (private, China) has 35% share in China only. Mitsubishi Electric and Toshiba have secondary positions.

Concentration: Very high. Top 3 players control an estimated 70 to 80% of the non-Chinese HVDC converter station market.

Entry barriers: Extremely high. Requires decades of power electronics expertise and research and development investment, installed reference base with major utilities, qualification with grid operators spanning 5 to 10 years per jurisdiction, proprietary technology in valve designs and control algorithms, engineering teams of hundreds of specialists, testing and simulation infrastructure, and capital intensity for manufacturing facilities.

India participation: Medium and growing. Hitachi Energy India is a joint venture partner with BHEL for the Bhadla-Fatehpur 6 gigawatt project. GE Vernova T&D India handles HVDC converter work for

POWERGRID. Both companies provide local project execution, but core technology remains with parent companies.

Tier 0: End Customers (Utilities, Grid Operators)

End customers own and operate transmission infrastructure, issue tenders for HVDC projects, provide project financing, and ensure grid integration and operation.

Market size: The global HVDC transmission market is valued at USD 15.62 billion in 2025, projected to reach USD 22.07 billion by 2030.

Key players: State Grid Corporation of China is the largest globally with over 50 HVDC lines. POWERGRID (India) is the central transmission utility driving HVDC deployment. TenneT (Germany/Netherlands) is the North Sea offshore grid developer. National Grid (UK) is a major HVDC project sponsor. Adani Energy Solutions (ADANIENSOL.NS, India) is a private transmission developer with the Bhadla-Fatehpur 6 gigawatt corridor.

Concentration: Fragmented globally, but concentrated within each jurisdiction through regulatory monopoly structures.

India participation: High. POWERGRID is the central transmission utility. Adani Energy Solutions won India's first HVDC transmission concession awarded to a private sector entity.

Tier 7: EPC and Project Developers

EPC and project developers develop, finance, and construct HVDC transmission projects, handling permitting, right-of-way acquisition, project financing, and construction management.

Key players: Adani Energy Solutions (India) is a leading transmission developer with Rs 18,000 crore in Q3 FY26 transmission project wins. Sterlite Power (private, India) has multiple corridor developments. L&T (India) secured a role in TenneT's HVDC offshore wind program, demonstrating Indian engineering capability entering European supply chains.

Concentration: Fragmented, region-specific. EPC capacity constraints are affecting project timelines, with HVDC equipment lead times creating delays.

India participation: High and growing. The private sector is increasingly participating in transmission infrastructure through the tariff-based competitive bidding mechanism.

Value Chain Summary Table

Tier	Description	% of End-Product Cost	Concentration	Avg Margin	Entry Barrier	India Participation
Tier 6: Power Semiconductors	Thyristors, IGBTs	3-5%	High	High (25-35%)	Very High	Near Zero (~5%)
Tier 5: Control Systems	MACH, protection, algorithms	10-15%	Very High	High (20-30%)	Extremely High	Very Low (~20%)
Tier 4: Reactors/Filters	Smoothing reactors, filters	10-15%	Moderate	Medium (12-18%)	Medium	Moderate (~60%)
Tier 3: Converter Transformers	HVDC converter transformers	20-30%	Moderate	Medium-High (15-22%)	High	High (~70%)
Tier 2: HVDC Cables	Submarine/underground cables	15-25%	High	High (15-20% for HVDC)	Very High	Very Low (~15%)

Tier 1: Converter OEMs	System integration	25-35%	Very High	High (18-25%)	Extremely High	Medium (~40%)
Tier 7: EPC/Developers	Project development	5-10%	Fragmented	Variable (8-15%)	High	High

HVDC Value Chain Structure

Source: Industry Research, FinancePulse

Tier	What It Includes	Key Players	Concentration	Margin Range
Tier 6	Power Semiconductors	Infineon, Mitsubishi, Hitachi	High (70%)	25-35%
Tier 5	Control & Protection	Hitachi (MACH), NR Electric	Very High	20-30%
Tier 4	Reactors & Filters	Hitachi, Siemens, Quality Power	Moderate	12-18%
Tier 3	Converter Transformers	Hitachi, Siemens, BHEL, TARIL	Moderate	15-22%
Tier 2	HVDC Cables	Prysmian, Nexans, NKT	High (2/3 EU)	15-20%
Tier 1	Converter Station OEMs	Hitachi, Siemens, GE Vernova	Very High (70-80%)	18-25%
Tier 0	Utilities / Grid Operators	State Grid, POWERGRID, TenneT	Fragmented	Regulated
Tier 7	EPC / Developers	Adani Energy, Sterlite Power	Fragmented	8-15%

5. Technology Shift: LCC to VSC and the Future of HVDC

The HVDC industry is in the midst of a technology transition from Line Commutated Converter (LCC) to Voltage Source Converter (VSC) systems. This shift is creating competitive differentiation opportunities for players with strong VSC portfolios, particularly for offshore wind and multi-terminal applications.

LCC vs VSC Technology Comparison

Line Commutated Converter technology has been the dominant HVDC topology since the technology's commercialization in the 1950s. LCC uses thyristor-based valves and requires a strong AC grid to support commutation. LCC systems have lower losses (typically 0.7 to 1.0% per station) and lower capital costs, making them preferred for long-distance bulk power transmission.

Voltage Source Converter technology uses IGBT-based valves in a modular multilevel converter architecture. VSC does not require grid support for commutation, enabling operation with weak or passive networks. VSC systems provide black-start capability, independent reactive power control, and smaller station footprint.

Characteristic	LCC	VSC
Power electronic device	Thyristors	IGBTs
Commutation	Line-commutated (requires grid support)	Self-commutated
Black-start capability	No	Yes
Reactive power control	Requires external compensation	Independent control
Station footprint	Larger	Smaller
Losses per station	0.7-1.0%	1.0-1.5%
Capital cost	Lower	Higher (18-25% premium in Europe)
Grid strength requirement	High (SCR > 2)	Low (can operate on passive networks)
Multi-terminal capability	Limited	Native support

Why VSC is Winning for Offshore Wind

VSC technology has become the preferred solution for offshore wind export cables for three structural reasons. First, offshore wind farms connect to weak AC networks or operate in islanded mode during commissioning, requiring black-start capability that only VSC can provide. Second, VSC's independent reactive power control simplifies grid integration for offshore substations. Third, VSC's smaller footprint reduces offshore platform size and cost.

Hitachi Energy and Siemens Energy have positioned their portfolios toward VSC, with extensive project track records. Hitachi Energy's Sofia 1.4 gigawatt offshore wind link and Viking Link interconnector demonstrate VSC capability. Siemens Energy is the preferred bidder for UK National Grid HVDC projects with VSC positioning.

The technology shift is creating pricing power for VSC-vested players. VSC technology commands an 18 to 25% price premium in Europe compared to LCC according to industry research. The premium reflects both the technology complexity and the supply-demand imbalance in VSC engineering capacity.

LCC Continues in China's UHVDC Backbone

China continues to invest in LCC technology for its ultra-high voltage direct current (UHVDC) backbone network, which transmits bulk power from western coal and renewable resources to eastern demand

centers. China operates the world's highest voltage systems including ± 1100 kilovolt UHVDC lines, all using LCC technology.

The LCC preference for China's backbone reflects the different use case. China's UHVDC lines transmit 10 to 12 gigawatts over distances exceeding 3,000 kilometers, where LCC's lower losses provide significant economic benefits over the project lifetime. The strong AC grids in China's eastern load centers support LCC commutation requirements.

NR Electric has developed control systems for world-first LCC projects including the Zhangbei ± 500 kilovolt HVDC grid and Gansu-Zhejiang ± 800 kilovolt VSC system, demonstrating that China is developing both technology streams.

India's Technology Selection

India's HVDC project mix reflects specific project requirements. The Bhadla-Fatehpur 6 gigawatt project uses LCC back-to-back technology, appropriate for grid-to-grid interconnection where both ends have strong AC networks.

The Leh-Kaithal Green Energy Corridor project in Ladakh requires VSC technology because the Ladakh region does not have a strong AC grid to support LCC operation. The project must function under difficult conditions: zero local inertia, very low short circuit ratio strength, and extreme terrain. India will adopt technology based on project-specific requirements rather than a blanket preference.

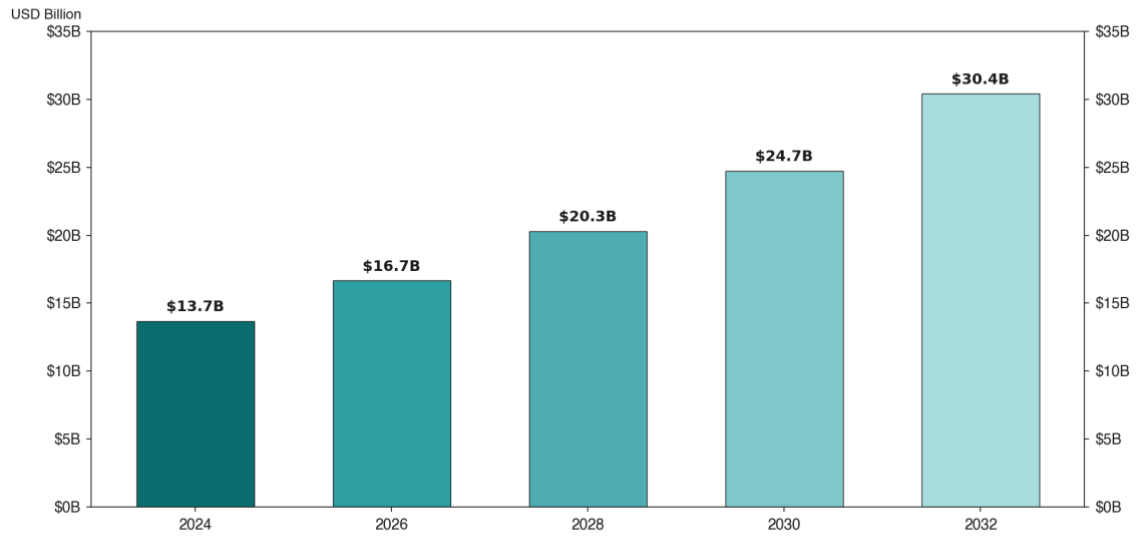
GE Vernova T&D India won a contract in December 2025 for a 2,500 megawatt, ± 500 kilovolt VSC terminal station for the Khavda-South Olepad HVDC project, demonstrating VSC adoption for renewable power evacuation in India.

Technology Roadmap

The industry is moving toward higher DC voltage ratings (525 kilovolts, 600 kilovolts, and even 800 kilovolts for VSC), requiring new qualification testing and manufacturing processes. Higher voltage systems increase power transfer capacity per cable, reducing the number of cables required for major transmission corridors.

Advanced grid support functions including synthetic inertia, frequency response, and oscillation damping are increasingly required by grid codes, deepening the advantage of established players with extensive operational experience. Control system complexity is becoming a differentiator.

CHART 2
HVDC Converter Station Market (CAGR 10.5%)



SOURCE: FORTUNE BUSINESS INSIGHTS, FINANCEPULSE

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6. Dedicated India Chapter: The World's Fastest-Growing HVDC Market

India represents the world's fastest-growing HVDC market, with a compound annual growth rate of 8.65% that exceeds the global average of 7.2%. The market is expected to reach USD 3.86 billion in 2025. The combination of aggressive renewable targets, grid infrastructure investment, and localization policy creates a structural opportunity for Indian equipment manufacturers while global technology leaders compete through joint ventures and subsidiaries.

Policy Context: 500 GW Target and Green Energy Corridors

India has set a target of 500 gigawatts of non-fossil fuel capacity by 2030, up from approximately 180 gigawatts in 2024. This represents one of the world's most aggressive renewable expansion programs. India has also committed to a 47% emissions intensity reduction from 2005 levels by 2035.

The Green Energy Corridors initiative was designed to evacuate renewable power from resource-rich states to demand centers. Phase I targeted evacuation of approximately 20 gigawatts. Phase II, approved by the Cabinet in 2022, targets an additional 20 gigawatts of renewable energy capacity evacuation.

The Central Electricity Authority estimates that Rs 2.44 lakh crore (approximately USD 30 billion) is needed for Inter-State Transmission System infrastructure to support the 500 gigawatt target. The breakdown includes Rs 2.16 lakh crore for 268 gigawatts of onshore renewable energy evacuation and Rs 28,100 crore for 10 gigawatts of offshore wind energy transmission infrastructure.

The structural lag between renewable installations and evacuation capacity has created a significant constraint. Approximately 40 gigawatts of renewable capacity is stuck due to lack of transmission infrastructure or power purchase agreements, according to Moneycontrol reporting from February 2026. POWERGRID's higher investment ceiling was approved in February 2026 to fast-track green energy transmission development.

Project Pipeline and Investment

The Bhadla-Fatehpur 6 gigawatt HVDC link is the flagship project demonstrating India's HVDC buildout. Awarded to the Hitachi Energy-BHEL consortium in April 2025, the 950 kilometer link will transmit renewable energy from the Bhadla solar park in Rajasthan to Fatehpur in Uttar Pradesh. Once commissioned, expected by 2028 to 2029, the link can power approximately 50 million households.

Adani Energy Solutions is developing a 6,000 megawatt integrated green energy corridor from Bhadla to Fatehpur, with financing secured from a Japanese bank consortium. The project represents Rs 25,000 crore in investment, with commissioning targeted for 2029. Adani Energy Solutions announced Rs 18,000 crore in transmission project wins in Q3 FY26, demonstrating the scale of private sector participation.

The Raigarh-Pugalur 6 gigawatt HVDC link, developed by POWERGRID with the first phase commissioned in November 2020, connects the western regional grid to the southern regional grid for bulk power transfer.

The Leh-Kaithal Green Energy Corridor project represents a unique challenge. POWERGRID received approval to start work on the project, which is expected to take approximately five years to complete due to extreme terrain and harsh climatic conditions. The project demonstrates India's commitment to connecting remote renewable resources.

India HVDC Project Pipeline

Project	Capacity	Developer	Status	Timeline
Bhadla-Fatehpur	6 GW	Hitachi Energy-BHEL JV	Awarded April 2025	Commissioning 2028-

				2029
Khavda-South Olepad	2.5 GW VSC	GE Vernova T&D India	Awarded December 2025	Under development
Adani Green Corridor	6 GW	Adani Energy Solutions	Financing secured	Commissioning 2029
Leh-Kaithal	Under development	POWERGRID	Approved	5-year construction
Barmer-South Kalamb	Under tendering	POWERGRID	Expected May 2026 award	Pipeline
Bikaner V-Begunia	Planned	POWERGRID	Expected FY27 award	Pipeline
Barmer-Jabalpur	Planned	POWERGRID	Expected CY27 award	Pipeline

The pipeline of LCC-based HVDC projects where competition is limited to Hitachi Energy includes Barmer-South Kalamb (Maharashtra, INR 200 to 250 billion), Bikaner V-Begunia (Rajasthan to Odisha, INR 200 to 250 billion), and Barmer-Jabalpur (INR 200 billion), according to industry research.

Localization Push and Manufacturing Capability

The Government of India's Make in India and Aatmanirbhar Bharat initiatives are driving localization across the HVDC value chain. The Central Electricity Authority identified 73 items used in the power transmission and distribution sector to formulate a comprehensive localization strategy based on criticality in December 2025.

The localization landscape shows significant variation by component:

Component	Localization Rate	Key Indian Players	Import Dependency
Converter transformers	~70%	BHEL, TARIL, TELK	Low-Medium
HVDC reactors	~60%	Quality Power, CG Power	Medium
Converter valves	~30%	BHEL-Hitachi JV, GE Vernova T&D India	High
Control systems	~20%	Limited	Very High
HVDC cables	~15%	Limited capability	Very High
Power semiconductors	~5%	None	Near 100%

The localization challenges are concentrated in control systems, cables, and power semiconductors, where technology remains proprietary to global original equipment manufacturers or requires manufacturing capability that India has not developed.

Indian Company Positioning

Bharat Heavy Electricals Limited (BHEL) is India's largest power equipment manufacturer with HVDC converter transformer capability. BHEL developed India's first ultra-high voltage AC 1200 kilovolt transformer in-house in February 2026, demonstrating technical capability for high-voltage equipment. The company is a joint venture partner with Hitachi Energy on the Bhadla-Fatehpur 6 gigawatt project, providing manufacturing capability while Hitachi Energy provides converter valve and control system technology.

BHEL earned the distinction of being the only manufacturer in the world to have successfully manufactured and tested ceramic disc insulators for +800 kilovolt UHVDC transmission systems at STRI. The company has an overall power transformer manufacturing capacity of 45,000 megavolt-amperes per annum, with its Bhopal Plant having annual capacity of 30,000 megavolt-amperes.

Financial performance shows recovery from the thermal power sector stress of the early 2020s. Revenue reached Rs 27,360 crore in FY25, up 19.4% year-over-year. Net margin is 1.9%, with return on equity at

3.32%, reflecting the competitive public sector market and legacy thermal exposure. Government backing through 63.2% promoter holding provides preferential access to public sector orders.

GE Vernova T&D India is the Indian subsidiary of GE Vernova, directly executing HVDC converter projects for POWERGRID. The company won a contract for a 2,500 megawatt, ± 500 kilovolt VSC terminal station for the Khavda-South Olepad HVDC project in December 2025, estimated at approximately INR 100 billion. Order backlog is estimated at INR 235 billion by Q3 FY26, representing approximately 4.5 times trailing twelve-month sales.

The company demonstrates strong profitability with 14.2% net margin and 58.8% return on equity. Direct access to parent GE Vernova's HVDC technology enables converter execution capability that BHEL lacks independently. The company is expanding its factory and building a test lab to produce key HVDC converters for the European market, potentially reducing the current 10-year wait time for essential components.

Quality Power Electrical Equipments is an Indian HVDC reactor manufacturer that recently listed and won Rs 34 crore in domestic HVDC reactor orders. The company represents India's emerging specialized HVDC component supplier, with high margins (21.3%) reflecting specialized product positioning. Small scale (Rs 775 crore revenue) and limited disclosure history constrain visibility. Working capital pressure with debtor days increasing from 113 to 149 warrants monitoring.

Transformers and Rectifiers India (TARIL) is the first Indian-origin company to win an HVDC converter transformer order from POWERGRID, validating technical capability. The company won a Rs 53.33 crore order for HVDC converter transformer repair and commissioning in December 2025. Strong margin improvement from 1% in FY21 to 10.4% in FY25 and return on equity of 21.8% demonstrate improving financial performance. Small scale (Rs 2,020 crore revenue) and component supplier status (no converter valve or control capability) limit value capture.

Adani Energy Solutions is India's largest private transmission developer with the Bhadla-Fatehpur 6 gigawatt HVDC project valued at Rs 25,000 crore. Under-execution order book of Rs 54,761 crore provides multi-year visibility. However, as a project developer and asset owner, the company does not control HVDC technology or manufacturing. High leverage with net debt to EBITDA of 4.55 times and declining margins from 12.3% to 4.5% over FY21 to FY25 reflect competitive tariff-based competitive bidding dynamics.

Competitive Dynamics vs Global OEMs

Indian companies operate as localization partners rather than technology competitors to global original equipment manufacturers. BHEL's joint venture with Hitachi Energy provides access to the MACH control system while meeting Make in India requirements. GE Vernova T&D India benefits from parent technology while executing projects domestically.

The strategic positioning creates a symbiotic relationship. Global original equipment manufacturers gain access to the fast-growing India market with localization compliance. Indian partners gain project execution opportunities and manufacturing scale. The technology dependency, however, means that Indian companies do not capture the highest-value components (converter valves, control systems).

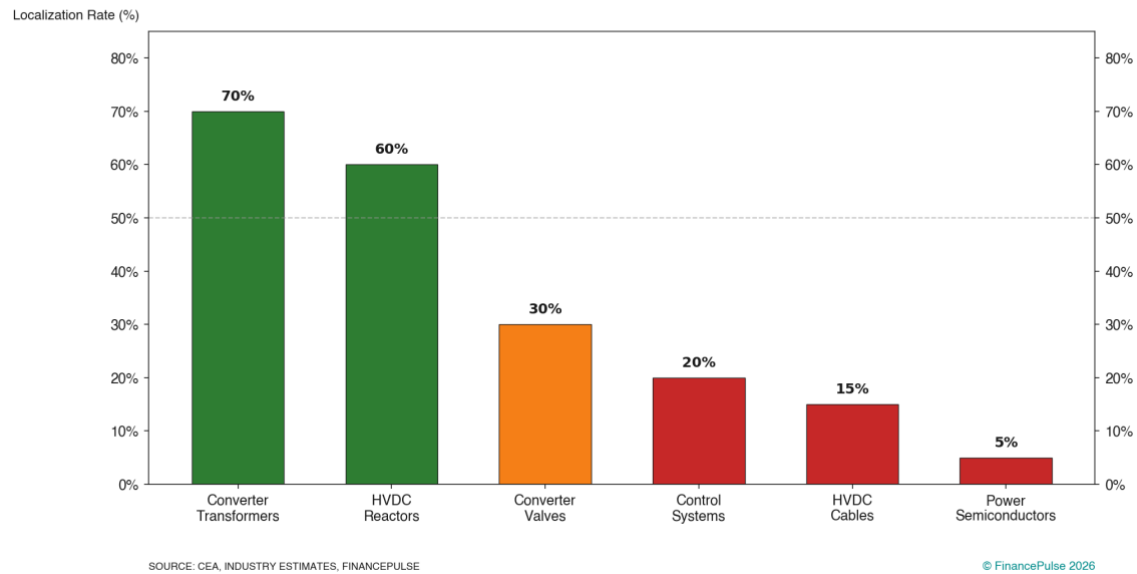
Tailwinds and Risks

India's HVDC buildout is supported by strong tailwinds. The 500 gigawatt renewable target creates sustained demand through 2030. Green Energy Corridor investments are accelerating with POWERGRID's increased investment ceiling. Make in India policies favor domestic manufacturers. Private sector participation through tariff-based competitive bidding is expanding transmission capacity.

However, significant risks remain. Import dependency on critical components (control systems, cables, semiconductors) creates exposure to global supply constraints and currency fluctuations. Joint venture structures provide technology access but may limit full capability development. Scale gaps between Indian manufacturers and global leaders affect cost competitiveness and technology investment capacity. Testing infrastructure is limited, with CPRI as the primary high-voltage testing facility, creating potential bottlenecks for qualification of new products.

The Rs 7.9 lakh crore investment in power transmission expected by 2036 to support over 900 gigawatts of non-fossil capacity, according to Business Standard reporting from March 2026, demonstrates the scale of the opportunity. The companies that can bridge the technology gaps while capturing localization tailwinds will be positioned to capture a decade of structurally higher growth.

CHART 4
India HVDC Localization Rate by Component



7. Structural Shifts: Geography, Policy, and Supply Chain Realignment

Geopolitics, trade policy, and supply chain resilience concerns are reshaping HVDC manufacturing geography, creating both opportunities and challenges for the industry.

Tariffs and Trade Policy Impact

The tariff environment is affecting HVDC equipment flows in complex ways. Tariffs on raw metals (copper, aluminum) affect input costs, but finished cable products may be exempt depending on trade policy design. Prysmian management noted that "tariffs are applied to metal and not to the derivative products" in the Q4 2025 earnings call, suggesting that finished cables may escape tariff impacts while domestic producers gain pricing power from import-competing positions.

Hitachi Energy has tariff pass-through mechanisms built into contracts, protecting margins from trade policy volatility. Management noted in the Q1 FY2025 earnings call that "the contract with existing customers is that when the tariff changes, the content of the contract changes accordingly. But for past contracts, we will consult with customers on a case-by-case basis." Customers are increasingly accepting tariff-related price increases, reducing margin pressure.

GE Vernova's Prolec acquisition in 2025 added transformer manufacturing capability in North America, the company's largest market. Prolec had invested approximately USD 300 million in existing or active capacity expansion programs, providing strategic flexibility for North American demand. The acquisition demonstrates the supply chain realignment toward regional manufacturing footprints.

European Manufacturing Expansion

European HVDC manufacturing capacity is expanding to meet North Sea offshore wind demand. GE Vernova announced expansion of manufacturing facilities in Stafford, UK, focusing on grid solutions and HVDC equipment. Sumitomo Electric is constructing a factory in Nigg, UK, for cable manufacturing. JDR is developing a facility in Cambois, and XLCC is building a facility in Hunterston, each representing significant investments in UK manufacturing capability.

NKT completed investment of a new test hall and capacity expansion in December 2025 to support high demand for high-voltage power cable accessories in Europe. Hydro signed a billion-euro deal to supply low-carbon aluminium wire rod to NKT for production of power cables to upgrade Europe's grid infrastructure, demonstrating the supply chain depth required for HVDC manufacturing.

The manufacturing expansion announcements by Siemens, Hitachi, and GE Vernova exceed USD 3 billion globally, but capacity remains tight through 2027 as lead times for new facilities extend 2 to 3 years.

US Inflation Reduction Act Implications

The US Inflation Reduction Act is catalyzing domestic transmission investment, with implications for HVDC infrastructure. Data center demand from artificial intelligence and cloud computing is concentrated in the US, driving transmission investment needs. Industry estimates suggest approximately USD 720 billion in grid spending through 2030 may be needed to support data center growth.

Hitachi Energy noted that "we still forecast a strong momentum in the U.S." and "Power Grid already have U.S. manufacturing base, and we are making quite a bit in the U.S. The demand is strong" in the Q1 FY2025 earnings call. US demand exceeds current capacity, requiring additional investment.

Regional manufacturing footprints are becoming strategically important as national security concerns around critical infrastructure grow. The Netherlands has categorized HVDC as critical infrastructure and limited participation to European firms, a trend that may extend to other jurisdictions.

India's Make in India Localization Requirements

India's Make in India policies are increasingly mandating domestic content for major transmission projects. The Central Electricity Authority identified 73 items in the power transmission and distribution sector for localization strategy in December 2025. POWERGRID tenders specify localization percentages, creating opportunities for domestic manufacturers.

The policy tailwinds benefit companies like BHEL, GE Vernova T&D India, Quality Power, and TARIL that have domestic manufacturing capability. Joint venture structures (BHEL-Hitachi Energy) enable technology transfer while meeting localization requirements.

Technology transfer partnerships represent a path to building domestic capability. The Economic Times reported in July 2025 that the government is planning to boost local manufacturing of critical power transmission equipment, especially for HVDC lines, through stakeholder discussions and technology acquisition initiatives.

Supply Chain Diversification Strategies

Original equipment manufacturers are pursuing geographic diversification to reduce supply chain concentration risk. Hitachi Energy has committed USD 6 billion capex for power grid capacity expansion across multiple regions. GE Vernova's Prolec acquisition adds North American transformer manufacturing. Prysmian's Encore Wire acquisition provides capacity flexibility to capture US market share from import-dependent competitors.

The trend toward regional manufacturing is structural rather than cyclical, driven by a combination of trade policy risk, national security concerns, and customer preference for domestic supply. The companies with diversified manufacturing footprints will be positioned to capture demand across policy regimes while managing trade policy volatility.

HVDC Value Chain Structure

Source: Industry Research, FinancePulse

Tier	What It Includes	Key Players	Concentration	Margin Range
Tier 6	Power Semiconductors	Infineon, Mitsubishi, Hitachi	High (70%)	25-35%
Tier 5	Control & Protection	Hitachi (MACH), NR Electric	Very High	20-30%
Tier 4	Reactors & Filters	Hitachi, Siemens, Quality Power	Moderate	12-18%
Tier 3	Converter Transformers	Hitachi, Siemens, BHEL, TARIL	Moderate	15-22%
Tier 2	HVDC Cables	Prysmian, Nexans, NKT	High (2/3 EU)	15-20%
Tier 1	Converter Station OEMs	Hitachi, Siemens, GE Vernova	Very High (70-80%)	18-25%
Tier 0	Utilities / Grid Operators	State Grid, POWERGRID, TenneT	Fragmented	Regulated
Tier 7	EPC / Developers	Adani Energy, Sterlite Power	Fragmented	8-15%

8. Evaluation Framework: How to Assess HVDC Companies

Not all HVDC companies are equal. The industry has extreme concentration at multiple tiers, creating winners who control chokepoints in the supply chain and others who face commoditization pressure. The companies that own proprietary technology, hold installed base moats, or control binding-constraint capacity will capture a decade of structurally higher margins. The framework below identifies six dimensions that separate durable outperformers from vulnerable participants.

The Six Criteria

1. Converter Technology Depth measures proprietary capability in HVDC converter station design, including valve technology, control systems, and project integration expertise. Converter stations represent 25 to 35% of HVDC project value and are the most technology-intensive component. OEMs with proprietary control platforms create customer switching costs and recurring service revenue. The shift from LCC to VSC technology favors players with VSC portfolios for offshore wind and weak-grid applications.

Global benchmark: Hitachi Energy demonstrates this at scale with over 150 GW of HVDC capacity integrated globally, the proprietary MACH control system deployed across major transmission systems, and VSC technology leadership including the Sofia 1.4 GW offshore wind link and Viking Link interconnector.

2. Cable Manufacturing Capacity measures ownership and operational control of HVDC submarine and underground cable manufacturing capacity, including access to cable-laying vessels for installation. HVDC cables are the binding constraint in global transmission buildout. Cable-laying vessel availability has 3 to 5 year lead times, and European manufacturers control approximately two-thirds of global HVDC cable capacity. Companies that own vessels capture preferential installation slots, reducing project execution risk.

Global benchmark: Prysmian Group demonstrates this at scale with EUR 19.6 billion revenue, the world's largest submarine HVDC cable manufacturing capacity, and ownership of four cable-laying vessels. Management confirmed capacity is fully sold out through 2029, with transmission EBITDA margins expanding toward 20.5% by 2028.

3. Backlog Quality and Duration measures the visibility, duration, and pricing trajectory of contracted future revenue. HVDC projects have 24 to 36 month lead times for converters and 4+ year lead times for cables. Companies with long-duration backlogs have visibility through demand cycles and can capture pricing improvements as capacity constraints persist.

Global benchmark: Prysmian's transmission capacity is sold out through 2029 with EUR 14 to 16 billion backlog. GE Vernova confirmed that slot reservation agreements are pricing 10 to 20% higher than existing backlog, with USD 150 billion total backlog (up 50% from USD 100 billion in 2022) and capacity visibility extending to 2030.

4. Geographic and Customer Diversification measures exposure across regions and customer types. HVDC demand is policy-driven and geographically uneven. Europe leads in offshore wind, the US is emerging for data centers and grid modernization, India is the fastest-growing market with localization requirements. Companies with multi-region presence can arbitrage policy timing and customer concentration.

Global benchmark: Hitachi Energy demonstrates this with presence across Europe, India (BHEL JV), Americas, and Asia Pacific.

5. Localization and India Positioning measures capability to capture India's HVDC buildout, either through domestic manufacturing, JV structures, or technology partnerships. India's 500 GW renewable target by 2030 and Green Energy Corridors create sustained HVDC demand. Make in India policies increasingly mandate domestic content for major transmission projects.

Global benchmark: GE Vernova T&D India demonstrates this with a listed Indian subsidiary that directly executes HVDC converter projects for POWERGRID, achieved 14.2% net margin (FY25) and 58.8% ROE, and maintains a net cash balance sheet.

6. Margin Durability measures ability to sustain margins through pricing power, contract structure, and operational leverage. HVDC is a seller's market with converter lead times at 24 to 36 months and cable capacity sold out through 2029. Companies with pricing power can pass through cost inflation and capture premium pricing.

Global benchmark: Prysmian's transmission EBITDA margins are expanding from 17.8% toward 20.5% by 2028. Hitachi Energy has tariff pass-through mechanisms built into contracts, protecting margins from trade policy volatility.

Score Scale Definition

Score	Definition
High	Company demonstrates leading or strong capability, with specific evidence of competitive advantage
Medium	Company has meaningful capability but lacks leading position or faces limitations
Low	Company has minimal or nascent capability, or is excluded from this criterion's value capture
N/A	Insufficient evidence to score, or criterion not applicable to company's value-chain role

HVDC Value Chain Structure

Source: Industry Research, FinancePulse

Tier	What It Includes	Key Players	Concentration	Margin Range
Tier 6	Power Semiconductors	Infineon, Mitsubishi, Hitachi	High (70%)	25-35%
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Tier 7	EPC / Developers	Adani Energy, Sterlite Power	Fragmented	8-15%

9. Company Profiles

Hitachi Energy (HTHIY)

Hitachi Energy is the global market leader in HVDC converter stations with estimated 30 to 35% of the non-Chinese market. The company has integrated over 150 GW of HVDC capacity globally, more than any competitor, with its proprietary MACH control system creating switching costs that no competitor can replicate. The company operates as a subsidiary of Hitachi Ltd, which has committed USD 6 billion capex for power grid capacity expansion.

Financial Profile: Hitachi Energy financials are not separately disclosed from parent Hitachi Ltd, a diversified industrial conglomerate. The Energy segment (which includes Hitachi Energy) contributed approximately 15% of consolidated revenue. Hitachi Energy India, the listed subsidiary, reported revenue of INR 6,384 crore in FY25 with 6.0% net margin and 23.4% ROE.

Metric	FY23	FY24	FY25
Revenue (INR Crore, India sub)	4,467	5,247	6,384
Net Margin %	2.1%	3.1%	6.0%
ROE %	N/A	N/A	23.4%

Value Chain Position: Tier 1 (Converter Station OEM), Tier 3 (Transformers), Tier 5 (Control Systems via MACH)

Key Contracts: Bhadla-Fatehpur 6 GW HVDC link (India, JV with BHEL), TenneT 2 GW Program (North Sea), Sofia offshore wind link (1.4 GW UK), Viking Link interconnector (1.4 GW UK-Denmark)

Management Evidence:

"\$6 billion investment capital expenditure has been decided and is carried out... The current order and capacity is at high level. So we have decided to make further investments in capacity to meet the demand." -- Toshiaki Tokunaga, CEO, Hitachi Ltd, Q4 FY2024 Earnings Call

"In Inspire 2027, energy growth is mentioned at 11% to 13%... at the level of the market growth CAGR 10% to 12%." -- Toshiaki Tokunaga, CEO, Q4 FY2024 Earnings Call

Framework Assessment: High on Converter Technology (MACH lock-in, 150+ GW installed base), High on Geographic Diversification, High on India Positioning (BHEL JV), High on Margin Durability (tariff pass-through contracts), N/A on Cable Capacity.

Siemens Energy (ENR.DE)

Siemens Energy is a major European HVDC OEM with strong VSC positioning and preferred bidder status for UK National Grid projects. The company recovered from Siemens Gamesa wind turbine quality issues in FY23 to deliver EUR 1.4 billion net income in FY25, with Grid Technologies margins expanding toward the upper end of 16 to 18% guidance.

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (EUR Billion)	31.1	34.5	39.1
Operating Income (EUR Billion)	-3.3	-0.05	2.1
Net Income (EUR Billion)	-4.5	1.2	1.4
Operating Margin %	-10.6%	-0.2%	5.4%

Key Metrics (TTM): ROE 18.13%, Net Debt/EBITDA -1.66x (net cash), Backlog EUR 146 billion (45% service)

Value Chain Position: Tier 1 (Converter Station OEM), Tier 3 (Transformers)

Management Evidence:

"We see really good structural demand, a record high and high quality order book and disciplined execution across all segments." -- Christian Bruch, CEO, Q1 FY2026 Earnings Call

"The midterm guidance by '28 will include an uplift of approximately 600 basis points for Gas Services and 500 basis points for Grid Technologies compared to prior targets." -- Maria Ferraro, CFO, Q4 FY2025 Earnings Call

"This also bolsters Europe's manufacturing resilience by supplying heavy-duty tanks for HVDC, generator step-up transformer and auto transformers up to 550 kV." -- Christian Bruch, CEO, Q1 FY2026 Earnings Call

Framework Assessment: High on Converter Technology (VSC leadership), High on Backlog Quality (EUR 146B, 45% service), Medium on Geographic Diversification (Europe-heavy), Low on India Positioning (limited exposure), Medium on Margin Durability (margin expansion underway).

GE Vernova (GEV)

GE Vernova is a US-headquartered HVDC OEM with strong India presence via subsidiary. The company won the Adani 6 GW HVDC order in December 2025, demonstrating competitive positioning in India's largest HVDC project. The Prolec acquisition in 2025 added transformer manufacturing capability in North America, the company's largest market.

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (USD Billion)	33.2	34.9	38.1
Operating Income (USD Billion)	-0.92	0.79	1.4
Net Income (USD Billion)	-0.44	1.6	4.9
Operating Margin %	-2.8%	2.3%	3.7%

Key Metrics (TTM): ROE 52.36%, Net Debt/EBITDA -2.40x (net cash), Backlog USD 150 billion

Value Chain Position: Tier 1 (Converter Station OEM), Tier 3 (Transformers via Prolec)

Management Evidence:

"When we look at where we're trending with our slot reservation agreements today versus our existing backlog, there's another 10 to 20 points of pricing strength in the SRAs today." -- Scott Strazik, CEO, Q4 2025 Earnings Call

"We added about \$12 billion of equipment backlog in Power. We added \$9 billion of services backlog in Power over the course of the year. Both are experiencing real margin accretion." -- Kenneth Parks, CFO, Q4 2025 Earnings Call

"The \$150 billion backlog we entered '26 with versus roughly \$100 billion in backlog that we entered '22 with." -- Scott Strazik, CEO, Q4 2025 Earnings Call

Framework Assessment: High on Converter Technology, High on Backlog Quality (USD 150B, pricing power 10-20% above backlog), High on Geographic Diversification (US, UK, India), High on India Positioning (subsidiary), High on Margin Durability.

Prysmian Group (PRY.MI)

Prysmian is the world's largest cable manufacturer with dominant HVDC submarine cable position. The company owns four cable-laying vessels, providing preferential access to the binding constraint in offshore HVDC execution. Transmission capacity is fully sold out through 2029 with EBITDA margins expanding toward 20.5% by 2028.

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (EUR Billion)	15.4	17.0	19.6
Operating Income (EUR Billion)	0.86	1.2	1.9
Net Income (EUR Billion)	0.53	0.73	1.3
Operating Margin %	5.6%	7.1%	9.7%

Key Metrics (TTM): ROE 22.15%, Net Debt/EBITDA 1.27x, Transmission EBITDA margin targeting 20.5% by 2028

Value Chain Position: Tier 2 (HVDC Cables)

Management Evidence:

"Our capacity is fully sold out through 2029. So a level of backlog between EUR 14 billion and EUR 16 billion is what we recognize more healthy." -- Massimo Battaini, CEO, Q2 2025 Earnings Call

"In terms of the transmission, TSOs have to digest the wave of order... for the next 5 years, we are flat out in transmission." -- Massimo Battaini, CEO, Q4 2025 Earnings Call

"The third one is the projects margin that we have in our backlog is better than what we executed in '25 or '24 or '23... This has given us confidence that the 20.5% top of the range is also achievable by 2028." -- Massimo Battaini, CEO, Q3 2025 Earnings Call

Framework Assessment: N/A on Converter Technology, High on Cable Capacity (vessel ownership, sold out through 2029), High on Backlog Quality (EUR 14-16B, margin accretion), Medium on Geographic Diversification (Europe-heavy), Low on India Positioning, High on Margin Durability (margin expansion).

Nexans (NEX.PA)

Nexans is the second-largest European HVDC cable manufacturer with strong offshore wind exposure. The company owns cable-laying vessels (Aurora, Nexans Skagerrack) providing installation capability, though smaller fleet than Prysmian. Transmission backlog reached EUR 7.9 billion in September 2025, providing multi-year visibility.

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (EUR Billion)	7.8	8.5	7.8
Operating Income (EUR Billion)	0.41	0.57	0.43
Net Income (EUR Billion)	0.22	0.28	0.35
Operating Margin %	5.3%	6.7%	5.5%

Key Metrics (TTM): ROE 11.17%, Net Debt/EBITDA 0.43x, Transmission backlog EUR 7.9 billion

Value Chain Position: Tier 2 (HVDC Cables)

Management Evidence:

"Both businesses, our submarine, both wind offshore and interconnections are basically positive in the outlook in the next 10 years." -- Julien Hueber, CEO, Q4 2025 Earnings Call

"Our Transmission adjusted backlog reached EUR 7.9 billion at the end of September, providing for Nexans a strong visibility for the coming years." -- Julien Hueber, CEO, Q3 2025 Earnings Call

"The cable that we have produced on store today belongs to the customers. So Nexans has no financial impact on this matter." -- Julien Hueber, CEO, Q4 2025 Earnings Call (on GSI contract rescheduling)

Framework Assessment: N/A on Converter Technology, Medium on Cable Capacity (vessel ownership, smaller scale), Medium on Backlog Quality (EUR 7.9B), Medium on Geographic Diversification, Low on India Positioning, Medium on Margin Durability.

NKT A/S (NKT.CO)

NKT is a specialized HVDC cable manufacturer with pure-play high-voltage exposure. The company is investing heavily in capacity expansion (FY25 capex EUR 743 million, 21% of revenue) but lacks vessel ownership, creating execution risk in the constrained installation market.

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (EUR Billion)	2.6	3.3	3.6
Operating Income (EUR Billion)	0.50	0.24	0.58
Net Income (EUR Billion)	0.12	0.34	0.28
Operating Margin %	19.2%	7.3%	16.1%

Key Metrics (TTM): ROE 13.74%, ROIC 14.79%, Net Debt/EBITDA -2.18x (net cash)

Value Chain Position: Tier 2 (HVDC Cables)

Key Contracts: Scottish HVDC links (EUR 2 billion, January 2026), Eastern Green Link 3, Taiwan JV with Walsin

Framework Assessment: N/A on Converter Technology, Medium on Cable Capacity (no vessel ownership, execution risk), High on Backlog Quality (record-high order backlog), Low on Geographic Diversification (Europe-focused), Low on India Positioning, Medium on Margin Durability.

BHEL (BHEL.NS)

BHEL is India's largest power equipment manufacturer with HVDC converter transformer capability. The company operates as a joint venture partner with Hitachi Energy for the Bhadla-Fatehpur 6 GW project, providing manufacturing capability while Hitachi Energy provides converter valve and control system technology. The company developed India's first 1200 kV UHV transformer in-house in February 2026, demonstrating technical capability. Hitachi Energy announced that the joint venture "will design and deliver HVDC terminals to transmit renewable energy from Bhadla, Rajasthan to Fatehpur, Uttar Pradesh in India. The 6 gigawatt (GW), 950 km HVDC link can power approximately 50 million households" (Hitachi Energy Press Release, April 2025). BHEL separately noted that "the company has developed India's first Ultra High Voltage AC 1200 kV Transformer in-house" (BHEL Press Release, February 2026).

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (INR Crore)	22,140	22,920	27,360
Net Income (INR Crore)	640	280	530
Net Margin %	2.9%	1.2%	1.9%

Key Metrics (TTM): ROE 3.32%, ROIC 1.36%, Promoter holding 63.2% (Government of India)

Value Chain Position: Tier 3 (Converter Transformers), Tier 4 (Reactors), Tier 7 (EPC via JV)

Framework Assessment: Low on Converter Technology (JV dependency), N/A on Cable Capacity, Medium on Backlog Quality, Low on Geographic Diversification (India domestic), High on India Positioning (JV partner, government backing), Low on Margin Durability (1.9% net margin).

GE Vernova T&D India (GVT&D.NS)

GE Vernova T&D India is the listed Indian subsidiary of GE Vernova, directly executing HVDC converter projects for POWERGRID. The company won a 2,500 MW VSC terminal order in December 2025, demonstrating HVDC positioning. The subsidiary achieved 14.2% net margin and 58.8% ROE in FY25, the highest profitability among Indian power equipment peers. The company announced that it "has won a significant contract from AESL Projects Limited for designing and establishing a 2500MW, 500kV HVDC VSC Terminal Station for renewable power evacuation from Khavda" (Company Announcement, December 2025). GE Vernova T&D India also "has been awarded a significant contract by Power Grid Corporation of India Limited (PGCIL) for the refurbishment of the 2x500MW HVDC Chandrapur back-to-back link" (Company Announcement, December 2025). Market recognition of the positioning is evident, as "GE Vernova T&D India's shares have surged 47% year-to-date, driven by a robust order pipeline including significant contracts from Adani Energy Solutions and Power Grid Corporation" (Economic Times, December 2025).

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (INR Crore)	2,770	3,170	4,290
Net Income (INR Crore)	(15)	180	610
Net Margin %	-0.5%	5.7%	14.2%

Key Metrics (TTM): ROE 58.8%, ROIC 49.0%, Net Debt/EBITDA -0.60x (net cash)

Value Chain Position: Tier 1 (Converter Station OEM - India execution), Tier 3 (Transformers)

Key Contracts: 2,500 MW VSC terminal for Khavda-South Olepad (December 2025), HVDC Chandrapur refurbishment

Framework Assessment: Medium on Converter Technology (parent-owned), N/A on Cable Capacity, High on Backlog Quality (major order wins), Low on Geographic Diversification (India domestic), High on India Positioning (listed subsidiary), High on Margin Durability (14.2% margins).

Quality Power Electrical Equipments (QPOWER.NS)

Quality Power is an Indian HVDC reactor manufacturer that recently listed and won Rs 34+ crore in domestic HVDC reactor orders. The company represents India's emerging specialized HVDC component supplier, with high margins (21.3%) reflecting specialized product positioning. CNBC TV18 reported that "Quality Power Electrical Equipments Limited announced receipt of multiple purchase orders worth approximately Rs 34 crores for supply of HVDC reactors from a domestic entity. The orders carry an execution timeline of 18 months" (February 2026). Whalesbook analysis noted that "Quality Power Electrical Equipments: Rs 146 Cr HVDC reactor orders secured. Execution in 18 months" (February 2026). TND India reported that "Quality Power Electrical Equipments Ltd has received its highest-ever annual order inflow in FY25 and its order backlog, as of March 31, 2025, was over Rs 750 crore" (August 2025).

Financial Profile:

Metric	FY24	FY25
Revenue (INR Crore)	~600	775
Net Income (INR Crore)	~120	165
Net Margin %	~20%	21.3%

Key Metrics (TTM): ROE 22.1%, P/E 58.1x, Order backlog Rs 750+ crore

Value Chain Position: Tier 4 (HVDC Reactors), Tier 3 (Specialty Transformers)

Framework Assessment: N/A on Converter Technology, N/A on Cable Capacity, Medium on Backlog Quality (Rs 750+ crore), Low on Geographic Diversification (India domestic), High on India Positioning (localization proxy), Medium on Margin Durability (21.3% margins, small scale risk).

Transformers and Rectifiers India (TARIL.NS)

TARIL became the first Indian-origin company to win an HVDC converter transformer order from POWERGRID in December 2025, validating technical capability. The company demonstrated strong margin improvement from 1% in FY21 to 10.4% in FY25, with ROE of 21.8%. TND India reported that "Transformers & Rectifiers (India) Ltd [TARIL] has received an HVDC transformer-related order from Power Grid Corporation of India Ltd (PGCIL), making it the first Indian-origin company to enter the field of HVDC converter transformers" (December 2025). Business Standard noted that "Transformers and Rectifiers (India) announced that it has secured an order worth Rs 53.33 crore from Power Grid Corporation of India for HVDC converter transformers and related works" (December 2025). The company "recorded the company's highest-ever annual order inflow during FY25" (TND India, April 2025). Business Today added that "Earlier this month, TARIL secured a Rs 53.33 crore order for an HVDC converter transformer and related works. Prior to that, it won a Rs 389.97 crore contract to manufacture transformers" (December 2025).

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (INR Crore)	1,370	1,290	2,020
Net Income (INR Crore)	41	45	210
Net Margin %	3.0%	3.5%	10.4%

Key Metrics (TTM): ROE 21.8%, ROCE 25.2%, Revenue CAGR 28.6%

Value Chain Position: Tier 3 (Converter Transformers)

Framework Assessment: N/A on Converter Technology, N/A on Cable Capacity, Medium on Backlog Quality, Low on Geographic Diversification (India domestic), High on India Positioning (first Indian-origin HVDC transformer supplier), Medium on Margin Durability (improving margins, small scale).

Adani Energy Solutions (ADANIENSOL.NS)

Adani Energy Solutions is India's largest private transmission developer with the Bhadla-Fatehpur 6 GW HVDC project worth Rs 25,000 crore. The company operates as a project developer and asset owner (Tier 0/7), not as an equipment manufacturer. Under-execution order book of Rs 54,761 crore provides multi-year visibility. The Adani Group announced that "Adani Energy Solutions Ltd. (AESL), India's largest private energy services company, has secured long-term financing from a consortium of Japanese banks for its flagship high-voltage direct current (HVDC) transmission project, Bhadla-Fatehpur HVDC" (Adani Press Release, February 2026). Business Today noted that "Adani Energy said it is the company's largest order win, taking its under-execution order book to Rs 54,761 crore and transmission network to 25,778 ckm and 84,186 MVA transformation capacity" (January 2025). NDTV reported that "Adani Energy Solutions Limited (AESL) has bagged the Bhadla (Rajasthan)-Fatehpur (Uttar Pradesh) HVDC (high voltage direct current) order, which is worth a whopping 25,000 crore" (January 2025). The company also announced "Rs 18,000 crore in transmission project wins in Q3 FY26" (Hans India, January 2026).

Financial Profile:

Metric	FY23	FY24	FY25
Revenue (INR Crore)	13,290	16,610	23,770
EBITDA (INR Crore)	5,970	7,610	9,810
Net Income (INR Crore)	1,260	1,140	1,060
Net Margin %	9.5%	6.9%	4.5%

Key Metrics (TTM): ROE 9.95%, Net Debt/EBITDA 4.55x (high leverage)

Value Chain Position: Tier 0 (Utility Owner), Tier 7 (EPC/Developer)

Framework Assessment: N/A on Converter Technology, N/A on Cable Capacity, High on Backlog Quality (Rs 54,761 crore), Low on Geographic Diversification (India domestic), High on India Positioning (largest private developer), Low on Margin Durability (declining margins, high leverage).

NR Electric (Private, China)

NR Electric is China's leading HVDC control and protection supplier, a subsidiary of NARI Technology under State Grid Corporation. The company developed control systems for the Zhangbei ± 500 kV VSC-HVDC grid (world's first HVDC grid at this voltage level) and the Gansu-Zhejiang ± 800 kV VSC project (world's first 800 kV VSC system).

Value Chain Position: Tier 1 (Converter Station OEM - Control & Protection), Tier 5 (Control Systems)

Key Projects: Zhangbei HVDC grid, Zhoushan 5-terminal VSC-HVDC, Gansu-Zhejiang ± 800 kV VSC

Framework Assessment: Medium on Converter Technology (VSC capability, China market only), N/A on Cable Capacity, N/A on Backlog Quality (private company, limited data), Low on Geographic Diversification (China domestic), N/A on India Positioning, N/A on Margin Durability (limited financial visibility).

10. Comparison and Capability Matrix

Framework Scoring Matrix

Company	Converter Tech	Cable Capacity	Backlog Quality	Geo Diversification	India Position	Margin Durability
Hitachi Energy	High	N/A	High	High	High	High
Siemens Energy	High	N/A	High	Medium	Low	Medium
GE Vernova	High	N/A	High	High	High	High
Prysmian	N/A	High	High	Medium	Low	High
Nexans	N/A	Medium	Medium	Medium	Low	Medium
NKT	N/A	Medium	High	Low	Low	Medium
BHEL	Low	N/A	Medium	Low	High	Low
GE Vernova T&D India	Medium	N/A	High	Low	High	High
Quality Power	N/A	N/A	Medium	Low	High	Medium
TARIL	N/A	N/A	Medium	Low	High	Medium
Adani Energy Solutions	N/A	N/A	High	Low	High	Low
NR Electric	Medium	N/A	N/A	Low	N/A	N/A

Financial Comparison Table

Company	Revenue (Latest FY)	Net Margin	ROE	Backlog	Net Debt/EBITDA
Hitachi Energy (India sub)	INR 6,384 Crore	6.0%	23.4%	N/A	-3.82x (cash)
Siemens Energy	EUR 39.1B	3.6%	18.1%	EUR 146B	-1.66x (cash)
GE Vernova	USD 38.1B	12.9%	52.4%	USD 150B	-2.40x (cash)
Prysmian	EUR 19.6B	6.6%	22.2%	EUR 14-16B	1.27x
Nexans	EUR 7.8B	4.5%	11.2%	EUR 7.9B	0.43x
NKT	EUR 3.6B	7.7%	13.7%	Record high	-2.18x (cash)
BHEL	INR 27,360 Crore	1.9%	3.3%	N/A	1.38x
GE Vernova T&D India	INR 4,290 Crore	14.2%	58.8%	INR 235B est.	-0.60x (cash)
Quality Power	INR 775 Crore	21.3%	22.1%	INR 750+ Crore	N/A
TARIL	INR 2,020 Crore	10.4%	21.8%	N/A	0.72x
Adani Energy Solutions	INR 23,770 Crore	4.5%	10.0%	INR 54,761 Crore	4.55x

India vs Global Comparison

Criterion	Global Leaders (Hitachi, Siemens, GE)	Indian Players (BHEL, GEV T&D, Quality Power, TARIL)
Converter Technology	Proprietary, decades of R&D	JV dependency (BHEL), parent-owned (GEV T&D), none (Quality Power, TARIL)
Cable Manufacturing	Vessel ownership, sold-out capacity	Import dependency, localization gap

Backlog Duration	3-5 years visibility	1-3 years visibility
Margins	15-25% converter, 15-20% cable	1-21% (wide range by positioning)
Geographic Reach	Global, multi-region	India domestic

HVDC Company Comparison Matrix

Source: Framework Analysis, FinancePulse

Company	Converter Tech	Cable Capacity	Backlog Quality	Geo Diversification	India Position	Margin Durability
Hitachi Energy	High	N/A	High	High	High	High
Siemens Energy	High	N/A	High	Medium	Low	Medium
GE Vernova	High	N/A	High	High	High	High
Prysman	N/A	High	High	Medium	Low	High
Nexans	N/A	Medium	Medium	Medium	Low	Medium
NKT	N/A	Medium	High	Low	Low	Medium
BHEL	Low	N/A	Medium	Low	High	Low
GE Vernova T&D India	Medium	N/A	High	Low	High	High
Quality Power	N/A	N/A	Medium	Low	High	Medium
TARIL	N/A	N/A	Medium	Low	High	Medium
Adani Energy	N/A	N/A	High	Low	High	Low
NR Electric	Medium	N/A	N/A	Low	N/A	N/A

11. Concluding Thoughts

The HVDC transmission industry is in the early years of a structural expansion that will last through 2030 and beyond. The demand drivers are policy-mandated and therefore durable: 7,000 GW of renewable capacity targets globally, 65 GW of North Sea offshore wind by 2030, 945 TWh of data center electricity demand by 2030, and India's 500 GW renewable target with USD 30 billion of transmission investment. These commitments lock in demand through the end of the decade regardless of economic cycles.

The supply side remains the binding constraint. Three companies control 70 to 80% of non-Chinese converter station capacity. European manufacturers hold two-thirds of global HVDC cable capacity. Cable-laying vessel lead times extend 3 to 5 years. Converter station engineering lead times stretch 24 to 36 months. This concentration creates pricing power that will persist until capacity catches up with demand, which I expect to take until at least 2028-2029.

The technology shift from LCC to VSC favors players with VSC portfolios. Hitachi Energy and Siemens Energy have positioned their converter offerings toward VSC, capturing the offshore wind and weak-grid applications that will drive the next phase of growth. The VSC premium of 18 to 25% in Europe reflects both technology complexity and supply-demand imbalance in VSC engineering capacity.

India represents the fastest-growing HVDC market globally at 8.65% compound annual growth rate, with the Bhadla-Fatehpur 6 GW project demonstrating the scale of transmission buildout required. The Make in India localization push creates a structural opportunity for Indian equipment manufacturers, though the technology dependency in converter valves and control systems means Indian companies will operate as localization partners rather than technology competitors to global OEMs.

The investment implications are straightforward. The companies that own the bottlenecks will capture the value. Hitachi Energy's MACH control system creates customer lock-in that protects margins through the cycle. Prysmian's vessel ownership and sold-out capacity provide pricing power that will drive transmission margins toward 20.5% by 2028. GE Vernova's slot reservation agreements are pricing 10 to 20% above existing backlog, confirming accelerating pricing power. Siemens Energy's Grid Technologies segment is targeting 500 basis points of margin improvement by 2028.

The risks are concentrated in execution. Large HVDC projects carry fixed-price contract risk. Manufacturing ramp-up challenges could delay capacity expansion. Trade policy volatility could affect input costs. The Siemens Gamesa experience in FY23 demonstrates that quality issues in one segment can create losses that overwhelm profitability in others. For Indian players, the technology dependency on global OEM partners creates a ceiling on value capture.

I believe the HVDC industry will sustain above-market growth through 2030, with pricing power persisting until capacity catches up with demand in 2028-2029. The companies that own proprietary technology, installed base moats, or binding-constraint capacity will deliver the strongest returns. For investors seeking exposure to the energy transition, HVDC transmission represents one of the most direct routes to capture value from renewable integration, offshore wind buildout, and the data center electricity boom.

