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Technological Overview of Global HVDC Market Till 2020

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Overview

Technological Overview of Global HVDC Market Till 2020

- High voltage direct current (HVDC) power transmission systems across the globe rely on DC (direct current) for the transmission of bulk power over long distances.
- HVDC systems are usually installed in three different configurations; namely: asymmetric monopole, bipole, and symmetric monopole.
- As far as the technological split in the regions are concerned, LCC technology has dominated all the regions with the exception of EMEA that too from 2010 onwards till 2020 where VSC technology gained traction.
- According to PTR study, HVDC transmission capacity in the EMEA, Americas, China, and Rest of APAC regions will expand to roughly 92 GW, 62 GW, 40 GW, and 37 GW, respectively, during the next ten to fifteen years.

- The VSC technology is expected to grow more in Europe and Americas regions where as the LCC technology will be used still in the Asia and few parts of Americas for long, high power and voltage rating transmission projects.

High voltage direct current (HVDC) power transmission systems across the globe rely on DC (direct current) for the transmission of bulk power over long distances. These HVDC systems include converter stations at both ends of the DC transmission line which convert AC to DC, and then back to AC in order for efficient transmission over long distances via DC power cable or overhead lines.

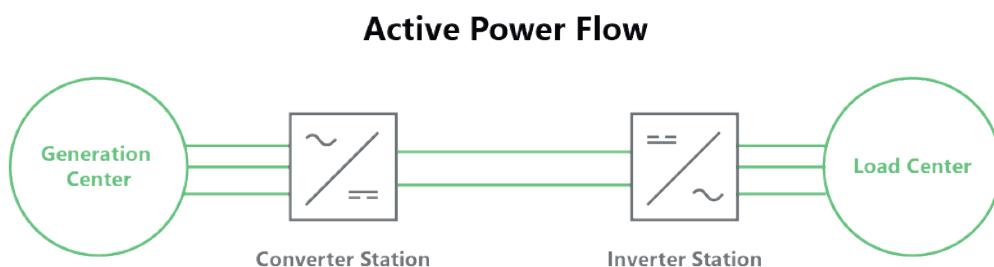


Figure 1: Single line diagram of a typical HVDC system.
Source: Power Technology Research

HVDC transmission systems are considered advantageous and, at times, superior to conventional AC transmission in applications that involve, for instance:

- 1) Underwater cable crossing, usually beyond 50 kilometers.
- 2) Transmission of bulk over long distances.
- 3) Stable interconnection, inter ties with low short circuit levels, coupling 50/60 Hz systems, and long-distance cable systems.
- 4) HVDC transmission lines have a smaller footprint compared to HVAC lines.
- 5) The capacitance between the active conductors and the surrounding earth or water curtails the length of HVAC lines or cables. If the HVAC cable is too long, no usable power would be transmitted from the source to the load center.

Configurations of the HVDC System

HVDC systems are usually installed in three different configurations; namely: asymmetric monopole, bipole, and symmetric monopole. Selecting the type of configuration always involves a tradeoff between the cost and power losses that incur during conversion and transmission.

Type of Configuration	Pros	Cons
Monopole	<ul style="list-style-type: none"> . Affordable as compared to other two configurations. a. No DC ground current b. Only one cable for ground return 	<ul style="list-style-type: none"> . Less Reliable- Loss of one pole means 100% outage a. Requires two cables for transmission accounting more power losses
Bipole	<ul style="list-style-type: none"> . No virtual DC ground current a. More reliable- Inherent redundancy is 50 % b. For same parameter of voltage and current provide double capacity than monopole 	<ul style="list-style-type: none"> . It is costly than monopole. a. Requires metallic return, in case there is no ground return
Symmetric Monopole	<ul style="list-style-type: none"> . No DC ground current is required. a. Require small capacity of cables and conductors b. Compatible with standard AC transformers 	<ul style="list-style-type: none"> . Less Reliable- Loss of one pole means 100% outage a. Requirement of two cables for transmission makes it costly b. Higher power losses than monopole configuration

Figure 2: Configurations of HVDC transmission systems.
Source: Power Technology Research

Furthermore, monopole and asymmetric monopole configurations have reliability issues as the loss of one pole results in 100% loss of load. So, they are less popular as compared to bipolar configuration which provides 50% redundancy in case of loss of one pole.

Major HVDC Technologies

Based on technology, specifically the switching element used in the converter stations, the global HVDC market is segmented into Capacitor Commutated Converter (CCC) based, Voltage Source Converter (VSC) based, and Line Commutated Converter (LCC) based.

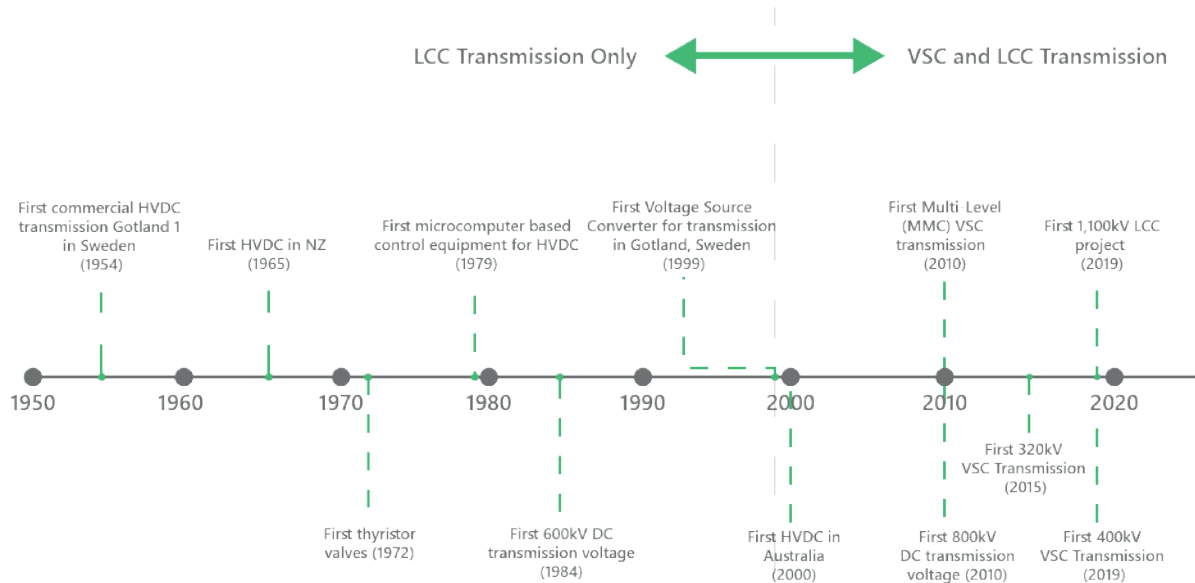


Figure 3: Evolution of HVDC technology over the decades.
Source: CIGRE Australia

Evolution of Technologies

In the mid-20th century, mercury valve-based HVDC systems were popular, but these were eventually replaced by thyristor valve-based HVDC systems that gained traction in 1980s. In the 21st century, IGBT (insulated gate bipolar transistor) valves converters outplayed all the previous technologies. This was mainly due to the availability of IGBTs with large blocking voltages and modules with high current-handling capability that enabled extending the VSCs developed for motor control applications to the HVDC transmission systems.

The IGBT-based VSC HVDC system gained traction among the giants of power equipment manufacturers; ABB group pioneered the introduction of VSC HVDC converters and named these VSC–HVDC valves HVDC Light. Siemens calls them the HVDC PLUS for Power Link Universal System, and Alstom's product is named HVDC MaxSine. With multilevel converters, the harmonic filtering, which occupied nearly half the LCC installation, can be reduced or eliminated. It is projected that the VSC–HVDC technology will completely displace the previous LCC-HVDC technology even for applications that require high voltage and power levels.

In recent years, the popularity of LCC HVDC systems has shifted to VSC HVDC systems, primarily in the Americas and Europe. However, LCC systems continue to have a substantial global presence because to their ability to transmit electricity at greater voltage and power levels than VSC systems due to their high short circuit ratio.

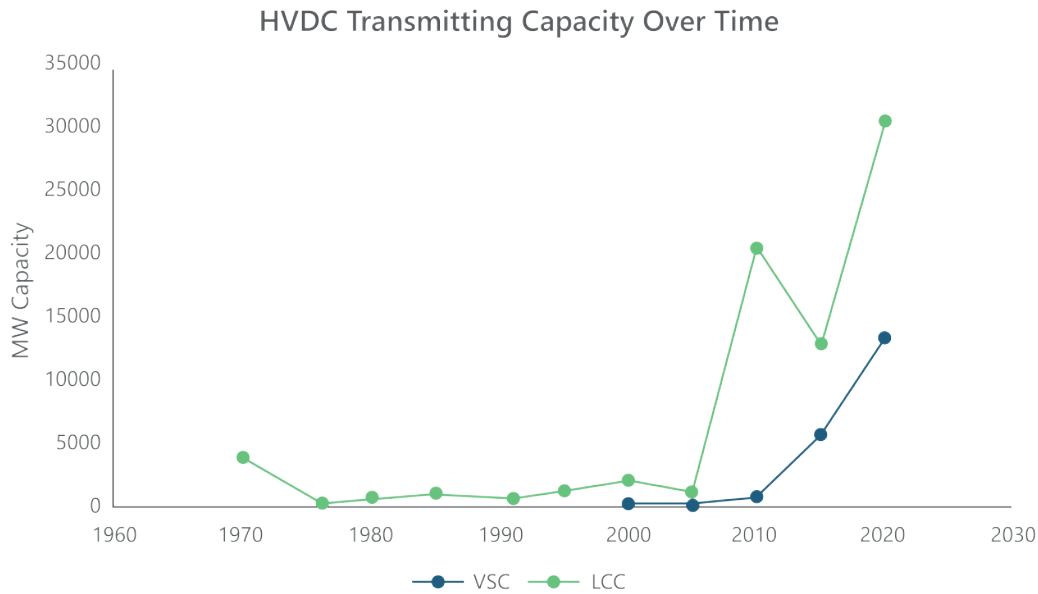


Figure 4: Global HVDC transmission capacity over time.
Source: Power Technology Research

Technology Split in HVDC

As far as the technological split in the regions are concerned, LCC technology has dominated all the regions with the exception of EMEA that too from 2010 onwards till 2020 where VSC technology gained traction. The share of VSC has gained traction in all the regions except China where no VSC based HVDC project was installed until the last decade. It is significant to note that China is a huge market which is the reason why it is placed next to regions to draw comparisons (Strictly speaking China does not qualify to be called a region but a country).

EMEA

In the last decade alone, several HVDC interconnections connecting different countries in the region have initiated their commercial operations. Europe leads the EMEA region in terms of cross-border HVDC interconnections; the Middle East and Africa have also invested in the development of HVDC infrastructure to tackle challenges associated with increasing load demand by integration diverse generating sources with the load centers. Currently, the EMEA has the capacity to transmit 50 GW of electricity through HVDC transmission links.

In order to support the integration of large amounts of renewables, mainly offshore wind farms in the North and Baltic Sea regions, VSC HVDC technology is expected to observe tremendous growth in the coming years. A few of the most recent projects that have been realized in this region are the Ethiopia-Kenya HVDC link, ALEGrO HVDC link (connecting Germany and Belgium), the North Sea Network (connecting the UK with Norway). VSC HVDC systems lead the regional market in the EMEA, accounting for 68% of the installations from 2011-2020, followed by LCC HVDC systems which accounted for 32% of the installations in the same period.

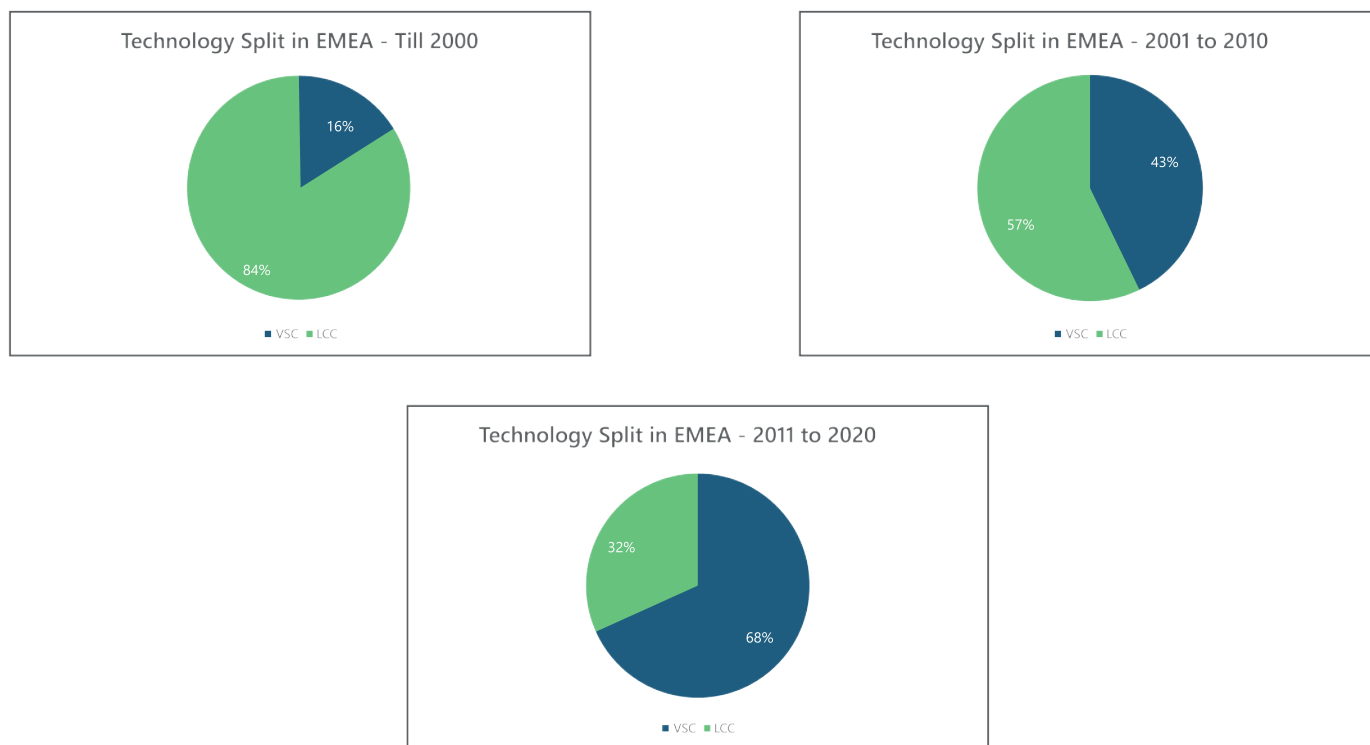
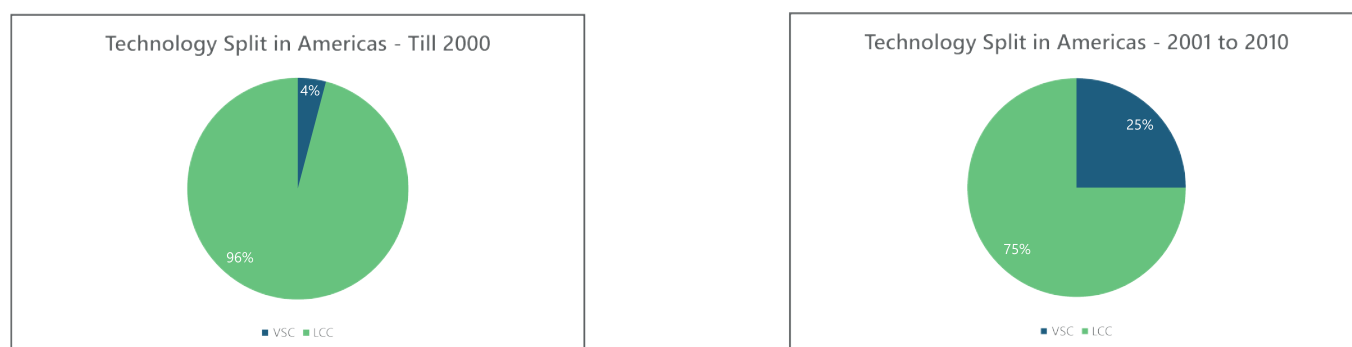


Figure 5: Technology split in EMEA.
Source: Power Technology Research

The Americas

In the Americas, Canada, the U.S. and Brazil are the major countries who have made significant investments in developing intra country and inter country HVDC transmission networks accounting for 50 GWs of accumulative electricity transmission capacity. As far as the technological split is concerned, LCC HVDC technology has a significant presence in the region owing to its high short circuit ratio followed VSC HVDC technology. Future market projections suggest that both VSC and LCC HVDC technologies will be deployed in the future to meet region's ever-increasing demand but the market share of VSC HVDC systems will be less than the share of LCC HVDC systems as majority of the Latin American countries are still developing economies that prefer cheap solutions. However, offshore wind farms deployment in the North America specifically at eastern coast of USA will boost VSC HVDC market in coming years.



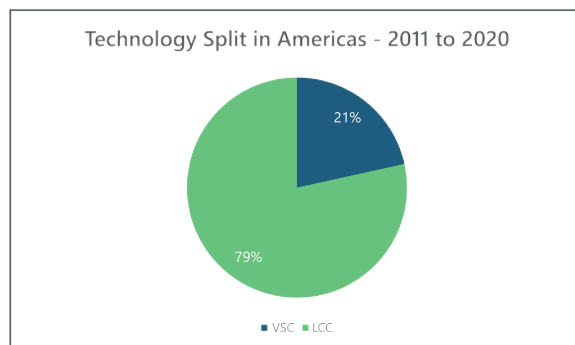


Figure 6: Technology split in the Americas.
Source: Power Technology Research

China

China itself is a huge market for HVDC transmission systems in the world and has made significant investments in the development of HVDC transmission infrastructure throughout the country especially during the last decade. Currently, it possesses 24 GW of transmission capacity through HVDC transmission networks.

As far as the technology split is concerned LCC HVDC technology dominated the HVDC transmission systems market of China accounting for 100% of the total installations till 2010. However, China adopted VSC HVDC in the last decade which is quite late as compared to the market of Americas and EMEA. LCC HVDC technology continues to have a dominant footprint in China mainly due to large scale transmission project requiring transfer of electricity at higher voltage and power levels. Recently, China has been successful in deploying high power VSC HVDC but at much higher cost than the LCC solution. Few of major HVDC transmission links includes Zhundong-Wannan/changji-guquan, Ximeng – Nanjing, Jiuquan-Hunan and Qinghai - Tibet(Golmud- Lhasa) HVDC link.

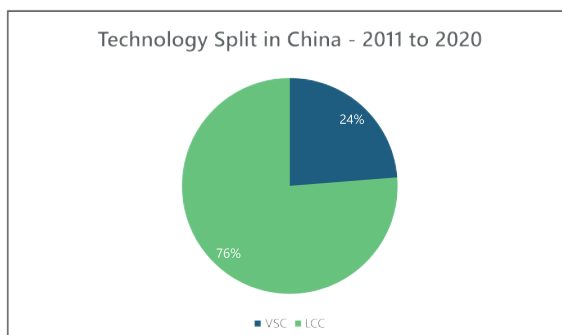
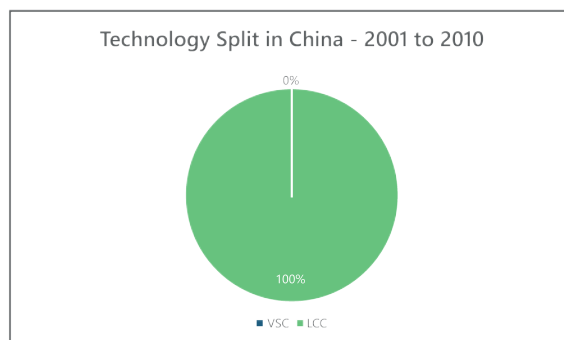
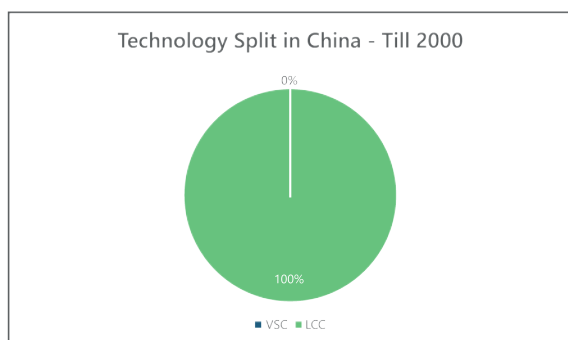


Figure 7: Technology split in China.
Source: Power technology Research

Rest of APAC

Rest of APAC includes Asian countries (except China) and Pacific region covering Australia and other neighboring countries. In this region India, Australia and Japan are the major markets which have invested in the HVDC technology in recent years. The region accumulatively accounts for approximately 41 GW of capacity to transmit electricity through HVDC links. Few of the major HVDC projects are Champa-Kurukshetra UHVDC (India), Kii Channel (Japan), Hokkaido-Tohoku (Hokuto-Imabetsu/Kitahon) (Japan), and Murraylink. In this region LCC technology is more popular due to its low cost and more capacity to transfer power from one generating source to load centers at higher voltage levels.

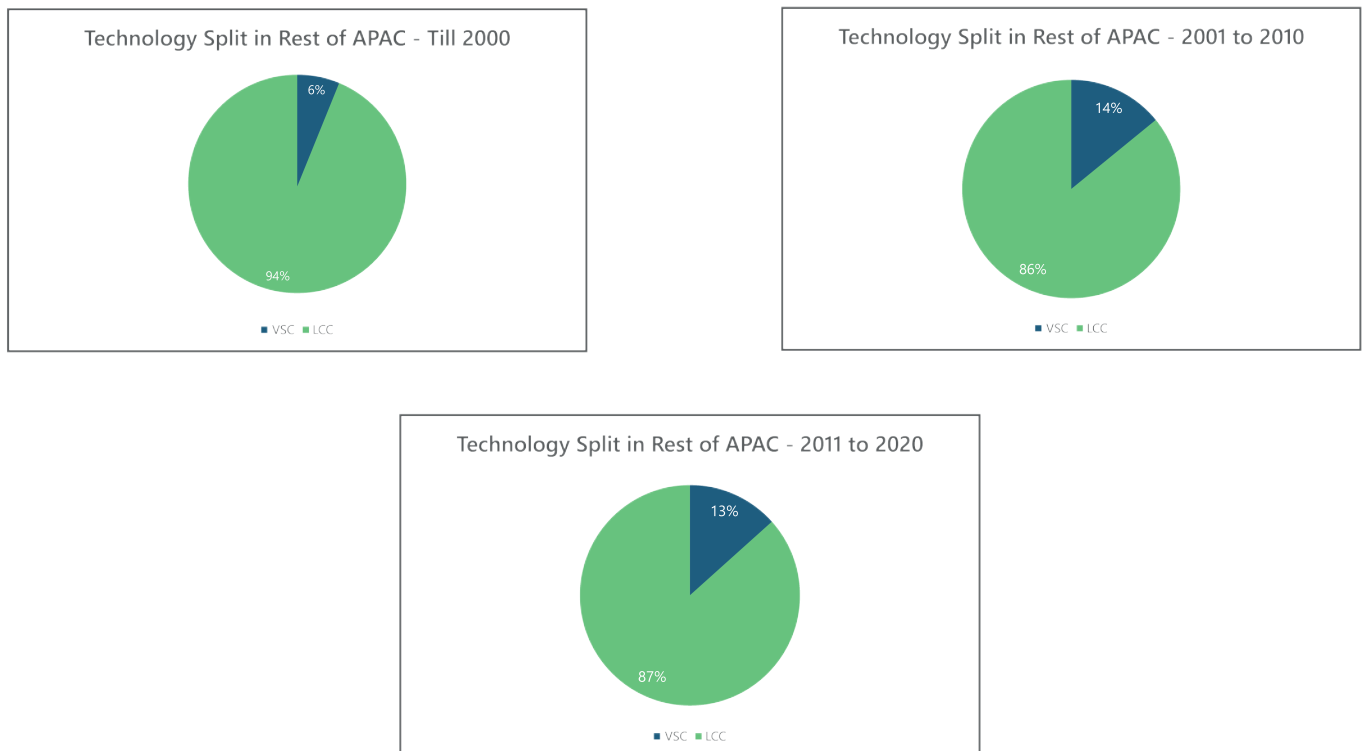


Figure 8: Technology split in rest of APAC.
Source: Power Technology Research

Looking Ahead


The HVDC transmission is vital technology to transmit electricity from renewable energy generation centers to the load centers or onshore grid infrastructure. With the growing trend of renewable energy deployment throughout the world, the HVDC industry is gaining pace. According to PTR study, HVDC transmission capacity in the EMEA, Americas, China, and Rest of APAC regions will expand to roughly 92 GW, 62 GW, 40 GW, and 37 GW, respectively, during the next ten to fifteen years. The VSC technology is expected to grow more in Europe and Americas regions whereas the LCC technology will be used still in the Asia and few parts of Americas for long, high power and voltage rating transmission projects.

The expansion in the deployment of renewables and push towards a single energy market is expected to drive the global HVDC transmission system's market in the upcoming years. Europe, Americas, and Asia

Pacific are leading in terms of deployment of renewable energy which in turn will be driving the demand for HVDC technology in these regions. As per Energy Information Administration of the US, the solar energy plus wind generation capacity increased by 28 GW in 2020. Solar generation capacity increased by 21 GW in 2022 whereas wind generation capacity increased by 7 GW by 2022.

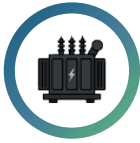
On the other hand, according to National Energy Administration, China has installed nearly 17 GW of offshore wind capacity in 2021 alone and country now accounts for around half of the global wind generation capacity that accounts for 54 GW.

Similarly, Europe is also aggressively pursuing the deployment of renewables mainly due to EU's renewable energy directive and national level renewable energy expansion plans. For instance, Germany which is leading EU member state plans to increase the share of renewables in the total energy consumption to 60% while generating 80% of the electricity from renewable resources by 2050.

The background image shows a vast industrial interior, possibly a power plant or a high-voltage substation. It is filled with large-scale electrical equipment. In the foreground and middle ground, there are several tall, vertical insulators or support structures made of stacked ceramic or porcelain discs. These are connected to complex networks of metal pipes, conduits, and structural beams. A large, horizontal cylindrical component, possibly a transformer or a large capacitor, is visible in the upper right. The ceiling is high and features a grid of structural elements and lighting fixtures. The overall atmosphere is one of industrial scale and complexity.

Power Technology Research's specialized market research coverage on Power Grid Equipment and Energy Transition Infrastructure provides clients a strategic advantage by enabling proactive decision-making supported by highly reliable data. Having worked for various blue-chip Fortune-500, FTSE-100, DAX-30 and NIKKEI-225 clients, Power Technology Research can assist you in identifying, valuing, and bench-marking opportunities in a multitude of topics within the power grid and energy transition space.

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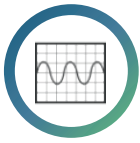
Synchronous Condensers
(4 - Pole, 6 - Pole,...)



Substation Automation
(Dist. vs Cent.)



DC Power Grid
(Shore to Ship, MVDC)



Power Factor Correction
(Active, Passive)



Grid Communication
(Private LTE, 5G)



Industrial Motors & Drives
(MV/LV - Custom)



Comm. & Off-Highway Vehicles
(BEVs, PHEVs, ICEs)



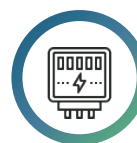
Storage Value Chain Monitor
(Utility Scale, C&I)



EV Charging Infrastructure
(Public, Private, Passenger/Comm.)



EV Traction Motors
(ACIM, PMSM, HTM)



Smart Meters
(Power Quality, AMI)



HVDC Market Analysis
(VSC, LCC)



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