How Crucial is HVDC for Energy Transition?

Landscape of HVDC Technology in North America and Europe

by **Qutab Baig**

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The world is undergoing an energy transition right now, especially the advanced economies in Europe and North America, in line with the Net-Zero targets and commitments made at the regional and international level. Within the energy sector, the debate is usually highly focused on power generation and the shift to cleaner resources, however, the transmission facilities, which are key enablers in evacuating this power to achieve desired transition, are often overlooked.

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One of the key elements within this infrastructure are the long-distance transmission lines. Historically, electricity over long distances has been transmitted through HVAC transmission lines and facilities, however, with the evolution of power electronics coupled with the need to integrate more and more renewables in the grid, HVDC transmission systems have also been regularly installed around the world.

The installations of HVDC systems can be segmented into three main applications: bulk power transmission, interconnecting grids, and infeed urban areas. HVDC systems are a popular choice for cross border interconnections. For instance, submarine cables are being installed to transmit power across regions and countries along with overhead HVDC lines, e.g. BritNed or Sardinia-Italy Mainland connections. These systems are best suited for supplying electricity to densely populated urban areas where significant obstruction could be caused by the density of overhead lines. One of the fastest growing applications of HVDC has been the offshore wind connection with the grid.

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Globally, there are more than 350 installed and upcoming HVDC projects, spread around the world, with the largest number of them being in APAC, followed by Europe and North America. This article will focus on two of these regions: North America and Europe.

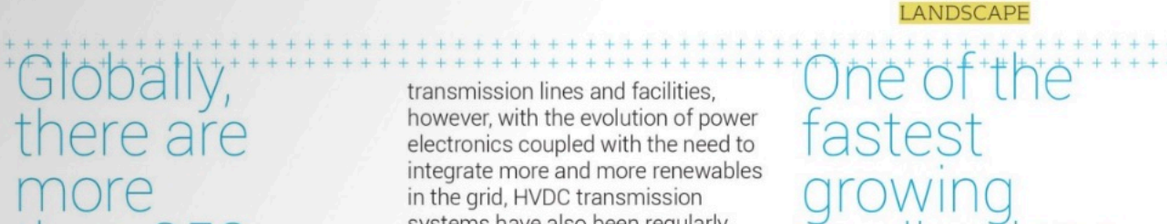

Figure 1. Timeline of deployment HVDC technology in the US (Source: Power Technology Research)

HVDC Market in North America

The North American HVDC transmission market is largely driven by the U.S. and Canada where sweeping majority of the region's HVDC transmission capacity is installed. Region's overall HVDC transmission capacity accounts for more than 32 GW, with LCC HVDC projects dominating the installed capacity. Figure 1 gives a brief timeline of key HVDC projects installed in the US.

Within North America, the U.S. current HVDC transmission capacity is around 20 GW. LCC HVDC technology is leading the market in the country with the majority of HVDC interconnections being nationwide, and with a few cross-border interconnection with neighboring countries. Canada, on the other hand, has a current HVDC transmission capacity of around 12 GW. The HVDC market in Canada experienced a boom in 1980s and in the last decade when majority of nationwide HVDC interconnection commenced their commercial operations. The Canadian HVDC market has been dominated by LCC HVDC, with the first VSC HVDC system, installed by ABB, starting its commercial operation in 2018. Beyond the U.S. and Canada, other markets in the region have very small installed capacities: e.g. Mexico has only one LCC project (Railroad DC Tie) with a capacity of 300 MW connecting Mexican national grid to ERCOT.

HVDC Technology Split in North America

Overall, the HVDC transmission market of the North American region is dominated by LCC HVDC technology. However, in the coming years, with the expansion of renewables, particularly offshore wind farms, more VSC HVDC systems are proposed by TSOs to enhance the reliability and transmission capacity of the transmission grid.

Until 2000, an overwhelming majority of the HVDC transmission systems installed in the region were LCC HVDC systems accounting for 95% of the total installations, whereas only 5% of the systems were VSC HVDC systems. From 2000 to 2010, majority of the projects installed were still LCC HVDC systems accounting for 71% of the total projects installed, but VSC HVDC technology gained traction accounting for 29% of the installed projects. In the last 10 years, the trend has been similar, with 67% of the projects installed being LCC HVDC systems, followed by VSC HVDC projects accounting for a slightly more than 33% of the total projects installed (Figure 2).

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HVDC Market Drivers in North America

The renewable energy targets, specifically the planned expansion of offshore wind along with the proposed legislation (if approved) and the loan guarantees from the Department of Energy for transmission projects in the U.S., will be the primary drivers of HVDC demand in North America.

The U.S. has a 25.4% share of renewables in the generation capacity mix and is planning to reach 80% of the capacity mix by 2030. On the other hand, Canada is already targeting to reach 90% renewables (including Hydro) by 2030. A big part of these targets is expected to be met through offshore wind energy. In the U.S., New York, Massachusetts, New Jersey, Maryland, and Virginia will be spending around USD 55 billion on 15 offshore wind energy projects in the next ten years, with the overall country-wide target of 30 GW offshore by 2030 set by Biden's administration. Most of these projects will be connected to the power grid using HVDC transmission interconnections, possibly funded via Electric Power Infrastructure Improvement Act or US DOE's Loan Program Office.

HVDC Market in Europe

Across the Atlantic in Europe, Germany, U.K., Italy, Denmark and France have the highest HVDC transmission capacity. The region has a cumulative HVDC transmission installed capacity of around 43 GW, with Germany leading the region in terms of installed HVDC transmission capacity, followed by U.K. and Italy.

Germany has an installed HVDC transmission capacity of 11.25 GW of electricity. German HVDC system in spread not only within the country itself, but also has interconnections with neighboring countries including Switzerland, Belgium, Sweden.

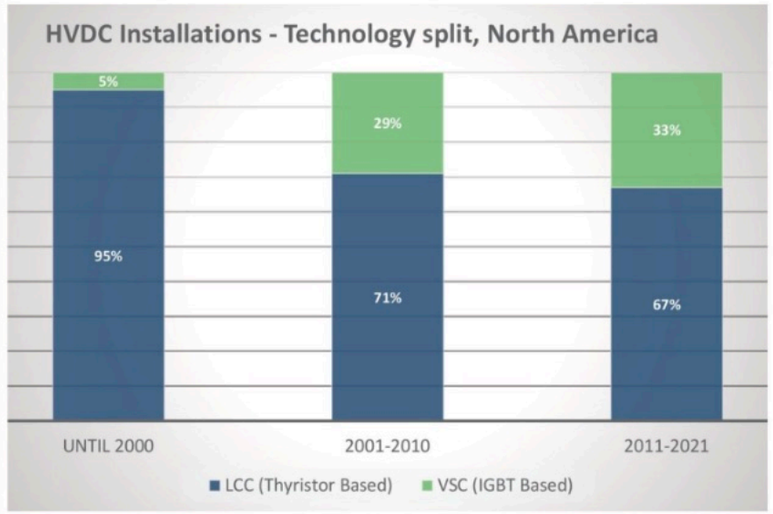

Figure 2. HVDC installations in North America (Source: Power Technology Research)

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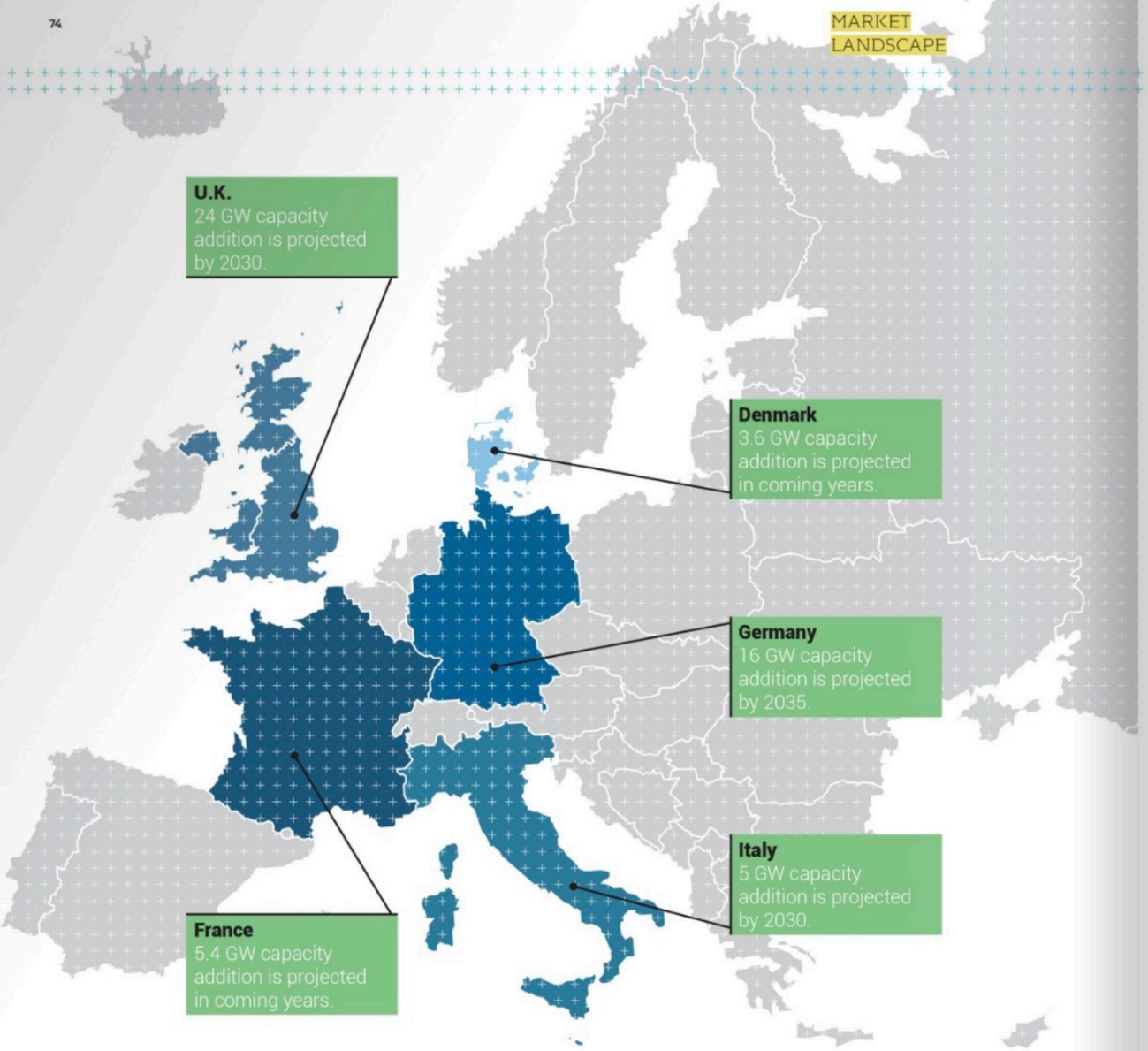

Figure 3. Top five HVDC markets in Europe (Source: Power Technology Research)

U.K., with the second largest installed capacity, hosts 6.4 GW of HVDC transmission capacity and the country has several cross border HVDC interconnections with France, Netherlands and Norway. However, the country is continuing to expand the transmission capacity through new HVDC projects to transmit electricity from the offshore wind farms in the North Sea back to shore. Italian HVDC transmission network has the capacity to deliver 3.7 GW of electricity from the generation center to load centers in the country. Italy also has a couple of cross-border HVDC projects connecting the Italian grid with grids of France and Montenegro.

HVDC Technology Split in Europe

The majority of the HVDC systems installed in Europe between mid-1970s and 2000 were thyristor based LCC HVDC systems. From 2001 to 2010, however, the VSC IGBT systems market experienced a substantial growth in the region as these systems provide a quick switching response compared to LCC Thyristor HVDC systems. VSC IGBT systems and LCC Thyristor systems accounted for 56% and 44% of the new installations respectively between 2001-2010. From 2010-2020, 72% of the installations in the region were VSC IGBT based while only 28% were LCC Thyristor based installations.

HVDC Market Drivers in Europe

Europe has set ambitious renewable energy targets, whose realization will provide a significant boost to the demand of HVDC transmission systems. Several regulations are in force in the E.U., such as the renewable energy directive and national renewable energy action plans, which are key driving factors in the transition to a low-carbon energy system. Europe is striving to become the first carbon neutral continent by 2050 and the targets have been set accordingly for deployment of renewables in the region. European Union has set a target of installing at least 60 GW of cumulative offshore wind by 2030 and 300 GW of cumulative offshore wind capacity by 2050.

Photo: Freepik

Moreover, the European Commission's directive has set a target of at least 10% interconnection capacity by 2020 and 15% interconnection capacity by 2030 to transmit electricity to neighboring countries. As the region pursues offshore wind energy targets along with the increase in the interconnection capacity, HVDC systems are expected to play a crucial role in transmitting this power in the continent.

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Moving Forward

The HVDC transmission is vital technology to connect these renewable energy generation centers with the load centers or onshore grid infrastructure. With the growing trend of renewable energy deployment throughout the world, the HVDC industry is gaining pace. Rollout of renewable energy resources, especially the offshore wind energy segment within the renewable category, along with the increasing cross-border connections within the E.U. and between the U.S. & Canada, will continue driving the demand for HVDC systems in these two regions.

The recent developments in the E.U. indicate that there is a huge potential for deployment of renewables which will give boost to the market of HVDC transmission systems needed to transmit power over long distances. Development of offshore wind power plants specifically is gaining a lot of traction in the North Sea and Baltic Sea regions, which will in turn provide a push to the HVDC transmission systems market in the region. Germany alone is planning to add around 16 GW of HVDC transmission capacity by 2035 focused on strengthening their nationwide HVDC infrastructure along with cross-border HVDC interconnections with Norway, Switzerland and Italy.

In North America, majority of the activity in the HVDC transmission systems market in the coming years will be seen in the U.S., which plans to install around 39 GW of HVDC transmission capacity till 2030. VSC HVDC systems are expected to overtake the LCC HVDC systems market as they provide a higher response rate suitable to integrate the power generated by offshore wind farms in the load centers. Canada is expected to install 4 GW of HVDC transmission capacity in the coming years, majority of which will be cross-border HVDC transmission capacity needed to import clean electricity to Canada from the U.S.

> The U.S. is planning to install around 39 GW of HVDC transmission capacity by 2030.

After a relative slowdown in new projects over the last couple of years, both regions are expected to grow significantly for the next few years, with sustained demand especially for IGBT based VSC HVDC systems. It is certainly important to keep a close eye on tenders and market developments, if your business is in any way related to HVDC technology.

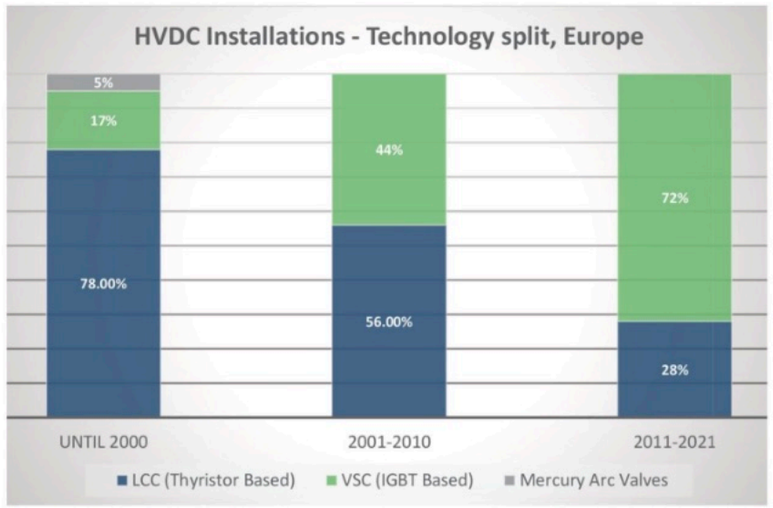

Figure 4. HVDC installations in Europe (Source: Power Technology Research)