

Power fulfillment with ABB's UHVDC and UHVAC transformers

By enabling high transmission voltages, large amounts of electric power can be transmitted over great distances at high efficiency. ABB has made groundbreaking developments in UHVDC and UHVAC transmission; today 1,100 kV DC and 1,200 kV AC is possible.

Mattias Viksten
Markus Pettersson
 HVDC transformers
 Ludvika, Sweden
 mattias.viksten@se.abb.com
 markus.pettersson@se.abb.com

Ryan Ladd
 Power Transformers
 Ludvika, Sweden
 ryan.ladd@se.abb.com

Energy demands are growing and a 70 percent increase in electricity consumption is anticipated by 2040, with over half of that growth expected in India and China [1]. As renewables increasingly become part of power generation in these countries, the need to transmit energy over greater distances with reduced losses becomes ever more desirable. However, the renewable energy sources can be located thousands of kilometers away from the load centers where electricity is needed. In these extreme cases, ultrahigh voltage (UHV) is often the most economical way to transmit the growing amount of power, and converter transformers are

the key technology for the essential link between the AC network and DC systems.

ABB has pioneered this enabling technology, working to increase voltage levels and developing groundbreaking components to meet the stringent requirements to transmit unprecedented power capacity ever farther under the harshest field conditions. ABB's 100 years of experience and expertise in the design and manufacture of transformers, along with a pioneering role in the development of HVDC transformer technology in the 1950s, provides the basis for their scientists and engineers to reach milestones in

ABB has made groundbreaking developments in UHVDC and UHVAC transmission; today 1,100 kV DC and 1,200 kV AC is possible

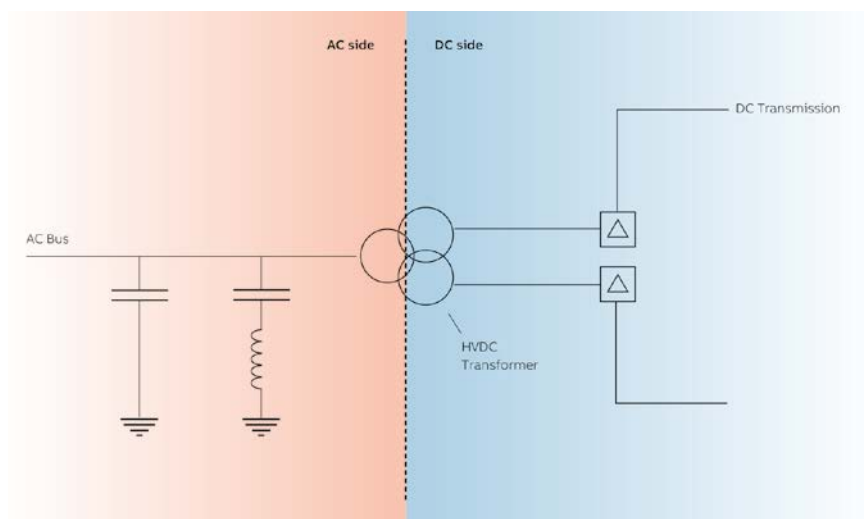


Figure 1. Simplified diagram showing the HVDC converter transformer function at the interface between the AC and DC sides.



Figure 2. Power transformer for 800 kV UHVDC transmission is shown.

1,100 kV DC and 1,200 kV AC transformers developed by ABB utilize the most advanced technology available

the development of power transmission, thereby establishing world records time and time again.

The high-voltage power transformers developed by ABB for 1,100 kV DC and 1,200 kV AC utilize the most advanced technology available. The most notable advancements have been made in improving dielectric performance but developments have also been achieved in all associated fields, such as thermal and mechanical performance.

The HVDC converter transformer

The HVDC converter transformer is unique in terms of the challenges it must overcome to function reliably and efficiently. Acting as the electrical and me-

chanical interface between the AC system and the DC converter, such transformers are exposed to the demands of both systems simultaneously, Figure 1.

The main function of the HVDC converter transformer is to insulate the DC-voltage of the converter valve from the AC-network to which the HVDC system is connected. All the power that flows through the HVDC system passes the converter transformers, thereby delivering current at a suitable voltage level to the converter valve, transformed from the AC network voltage level.

Converter transformers are typically large in terms of physical size due in part to the high power ratings, and because both windings necessitate a high degree of insulation; the AC winding is often

connected to high-voltage AC grids while the DC winding has heightened insulation requirements.

For this reason, dielectric performance is vital to the design of HVDC converter transformers. Converter transformers must not only withstand AC-stress, but also DC-stress generated during tests and service of the DC transmission system. Designing converter transformers to withstand DC-stress has proven to be one of the most complex and formidable challenges undertaken by engineers who design this enabling technology. Thus, HVDC converter transformers are the most rigorously tested transformers in the entire transformer industry.

Comprehensive testing must also be applied to the bushings and tap-changers. ABB's unique position to design and manufacture these devices in-house – relying on unprecedented expertise and experience allows ABB to develop sophisticated designs and deliver the most reliable and optimized transformers possible on schedule.

Development of UHVDC converter transformers

The Itaipu HVDC power link in Brazil, developed and installed by ABB in the early 1980's, was a complex megaproject that pushed the limits of voltage levels and power capacity beyond the then established norms. The system reached an outstanding power transmission level of 3,150 MW and a voltage level of 600 kV DC – a world record voltage level that remained unsurpassed for 25 years. Nearly all devices and components used for this HVDC project were designed and developed by ABB. Viewed in retrospect this project ushered in the modern era of HVDC technology within ABB.

The first Chinese HVDC transmission systems were rated 3,000 MW and 500 kV DC, delivering an Itaipu-type transmission power and voltage level. An important outcome of these early HVDC projects was the realization that it is possible to have single infeed points in

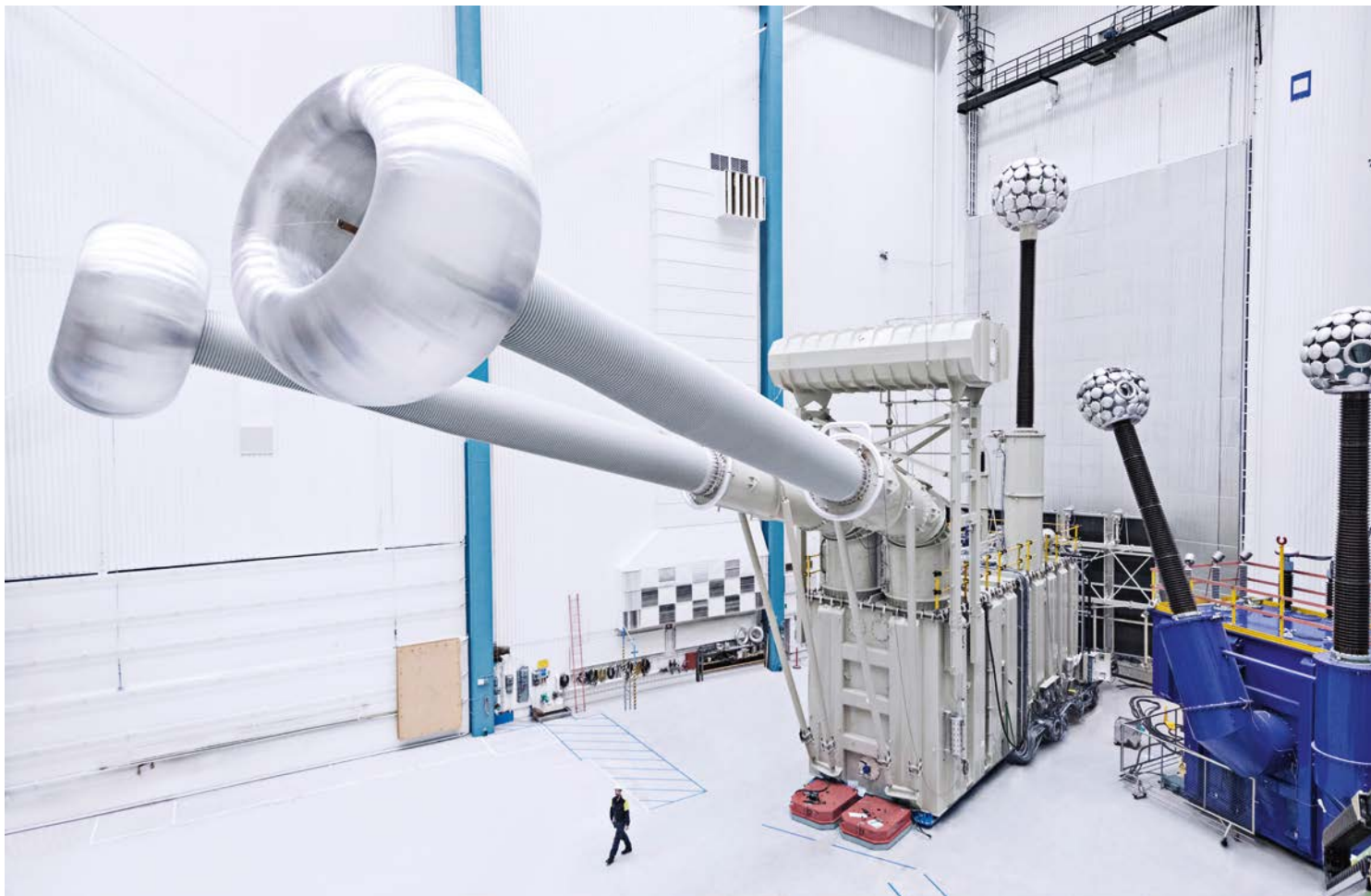
networks that can handle substantially more than 3,000 MW. China has access to energy resources, increasingly from renewables, with transmission distances far from load centers – i.e., 2,000 km. The possibility of such a large power infeed and the enormous distances to the load led to the investigation of a new voltage level of 800 kV DC – ultra-high-voltage DC (UHVDC). Thus, an even higher power transmission rating was feasible; a rating that is required by the Chinese electric energy market. The Xiangjiaba- Shanghai HVDC project was thus the first 800 kV UHVDC transmission system to go into commercial operation with a power rating of 6,400 MW and a transmission voltage of 800 kV DC; it has operated successfully since 2010 [1], Figure 2.

ABB has developed the ability to interconnect all existing DC-transmission voltage levels to all existing AC network voltage levels

The ability to transmit huge amounts of power over thousands of kilometers led, in 2011, to the next major HVDC transmission development – 1,100 kV UHVDC. In 2016, ABB was awarded a contract to supply the world's first 1,100 kV DC converter transformers, for the 3,000 km, 12,000 MW Changji-Guquan UHVDC link, inaugurating the commercial development of 1,100 kV DC, Figure 3.

The rapid development of HVDC technology over the past five years, from 800 kV DC to 1,100 kV DC, is both noteworthy and remarkable considering that the step from 600 kV DC to 800 kV DC took 25 years, Figure 4.

Recently, two further groundbreaking developments have been achieved in the



Domain expertise and experience, coupled with the most modern test facilities and innovative simulation tools, make ABB the world leader in the development of HV power transformers

HVDC transformer domain that continue to demonstrate ABB’s leadership role in transformer innovation and customer commitment. One such advancement concerns the power rating for 800 kV DC transmission links, which was increased from 8,000 MW to 10,000 MW. To raise the power rating by 25 percent, ABB redesigned the thermal system to cope with the increased current for the converter transformer. The technical challenge of increased physical size and scale due to the power increase was also successfully addressed. Consequently, ABB supplied converter transformers for the world’s first 10,000 MW, 800 kV UHVDC transmission project and other similar projects.

Another breakthrough concerns the AC-voltage level of HVDC converter transformers. ABB has developed the ability to interconnect all existing DC-transmission voltage levels to all existing AC network voltage levels. The LingShao project was the first commer-

cial application of this new technology. ABB’s converter transformers facilitated the interconnection of 750 kV AC network with an 8,000 MW, 800 kV HVDC-transmission. The successful type testing of this technology resulted in a contract award – the JiuQuan-Hunan project. The supply of leading edge converter transformers and components facilitates long distance transmission of electricity with reduced losses and showcases the ability of HVDC to reinforce the AC grid.

In the first commercial application of 1,100 kV UHVDC-transmission, ABB’s converter transformers are also connected to a 750 kV AC network; this demonstrates the trend of UHVAC to UHVDC interconnection.

UHVAC transformers

Lately, ABB has been able to raise the voltage level of AC networks and significantly improve transformer capabilities.

The same motivation was used to drive gains in AC voltages to facilitate the efficient long distance transmission of electricity.

Although ABB has been producing UHVAC transformers for many years, a major breakthrough was achieved in 2016 when ABB delivered the world’s first commercial 1,200 kV AC transformer to a substation in India. Fully assembled, this single-phase 333 MVA, 1,200 kV autotransformer weighs 270 tons and is over 9 meters in length, more than 8 meters wide and more than 18 meters in height. ABB’s HV bushing extends 11.5 meters from the top of the transformer tank, which weighs up to 6 tons, Figure 5.

Case study - the 1,100 kV DC project

Major load centers are located in the eastern region of China, while a significant amount of its energy resources, such as hydropower, are located in the west and northwest [1]. The expansive geography and increased energy demand experienced over the last decade have prompted the buildup of ultrahigh-voltage capacity to transmit larger amounts of power over greater distances with minimum losses. One example of this is the 1,100 kV Changji-Guquan UHVDC project that will transmit 12 GW from

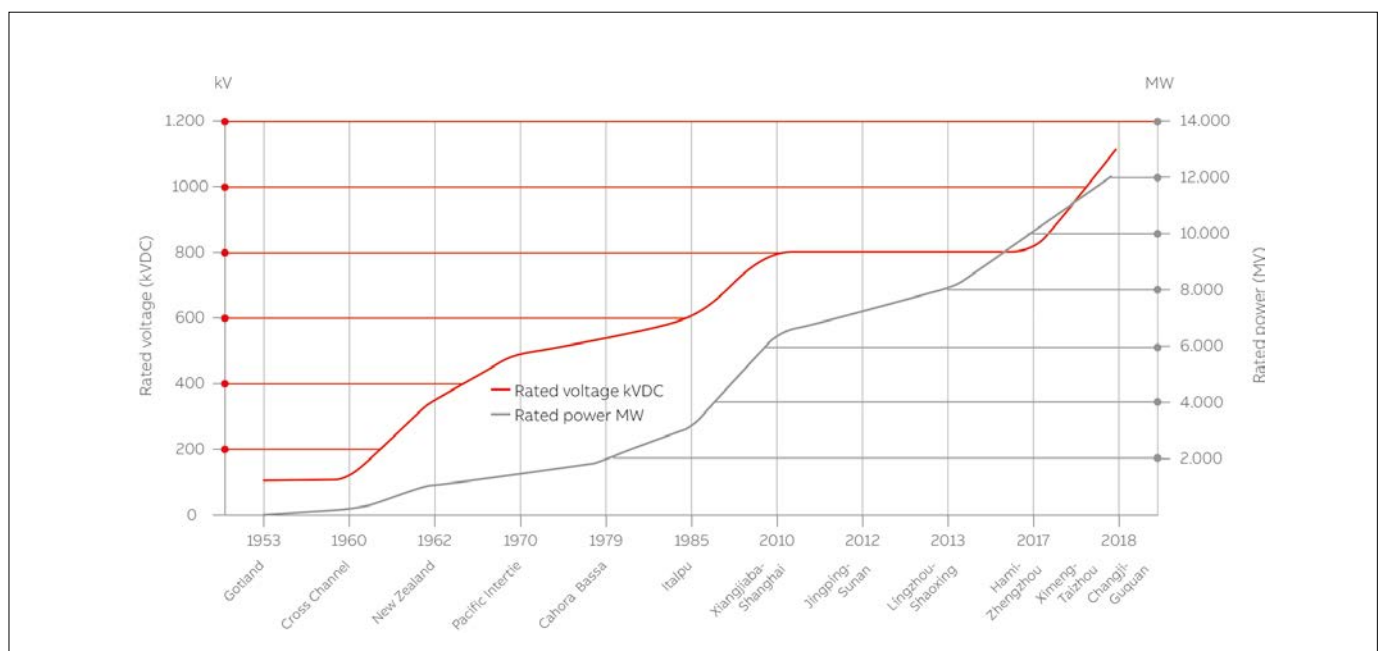


Figure 4. The advancement of HVDC converter transformer technology has led to flexibility in HVDC transmissions – almost any conceivable rating combination is possible.

the Xinjiang region in the Northwest to Anhui province in eastern China and will set a new world record in terms of distance, voltage level, and transmission capacity – a 50 percent increase in transmission capacity compared to the existing 800 kV 8 GW UHVDC currently in operation [1].

The giant converter transformers developed for this project are essential because the transmission distance will be extended from around 2,000 km to over 3,000 km, thereby playing a key role in integrating remote renewables on a large scale. Power can then be transmitted over greater distances; this will facilitate a more interconnected grid. When fully operational, this UHVDC link will deliver enough power

to meet the needs of a megacity larger than Shanghai.

The single-phase HVDC transformers developed by ABB have a power rating of 607 MVA and an installed weight of more than 800 tons. The DC-side bushings of this transformer are 40 percent longer, three times heavier and have a 30 percent larger diameter than the 800 kV DC bushing. The technical innovation required to design and build components of this size and scale challenge even the world's most advanced production and testing facilities to the limit.

ABB Ability™

The ability to monitor and control the performance of transformers that op-

erate at such high powers and voltages is critical. To ensure that operators are alerted in case of any problems, devices that monitor temperatures and transformer oil status are essential and therefore installed.

In the near future, ABB will extend this monitoring capability with the development of the ABB Ability™ Power Transformer. This package of integrated devices will enable sophisticated aggregation, analysis and management of transformer health data – ensuring customers have access to the most reliable and efficient product possible and providing the means to incorporate all advances in the emerging digital revolution to come [2].

Domain expertise and experience coupled with the most modern test facilities and innovative simulation tools make ABB the world leader in the development of high-voltage power transformers – a market position that allows it to develop the most powerful transformer solutions for its customers.

References

[1] Game Changers in the Energy System Emerging Themes Reshaping the Energy Landscape, McKinsey & Company, World Economic Forum 2017, “www3.weforum.org/docs/WEF_Game_Changers_in_the_Energy_System.pdf”

[2] M. Berglund, M. Peterssen, T. Freyhult, R. Montano, “Developments in UHVDC and UHVAC Transmission Power transformers,” ABB white paper, 2016.



Figure 5. ABB's 1,200 kV AC transformer was developed, manufactured and tested at ABB's Vadodra facility in India and currently supports India's central transmission utility, at Bina India.



pdf edition of ABB Review, Special Edition Transformers 2018.

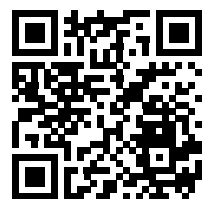


ABB Review

This article was first published in ABB Review, Special report on Transformers, 2018.