Ultra high voltage
Developments in power transformers technology
The increasing demand in recent decades of UHV (ultra-high voltage) DC transmission lines for high power transmission over very long distances (greater than 1000km) has driven the need to developing UHVDC converter transformers technologies. ABB succeeded in developing and tested the world’s first 1,100kV UHVDC converter transformer prototype, breaking the record for the highest DC voltage levels, in June 2012. Expanded power ratings of converter transformers leads to increased physical size, while the transport restrictions for transporting converter transformers remain the same. ABB has succeeded to develop these converter transformers with high power and voltage levels within narrow transport profiles. Based on the HVDC converter transformer development mainly for UHVDC a much greater flexibility of HVDC transmissions has been created. Nearly all conceivable rating combinations can be realized. The ultimate conclusion from this is that there is no limitation in what optimization can be made for future HVDC transmissions in terms of DC transmission voltage or power level or to which AC network the HVDC transmission is connected.

UHVDC converter transformers enable efficient and reliable transmission of large amounts of electricity across long distances. The powerful 1,100 kV transformers are a historical step towards a demanding future.

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From Gotland to 1,100kVdc – still pioneering HVDC

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The transformer evolution
From 800 kV to 1,100 kV UHVDC

New world record in terms of voltage level, transmission capacity and distance.

In 2016, ABB won an order to deliver the world’s first 1100 kV Changji-Guquan UHVDC link in China. The link will transmit power from the Xinjiang region in the Northwest, to Anhui province in eastern China and will set a new world record in terms of voltage level, transmission capacity and distance. It will be capable of transporting 12 gigawatts (GW) of electricity – the equivalent of 12 large power plants, a 50 percent increase in transmission capacity, compared with the existing well proven 800 kV (8GW) UHVDC links currently in operation. This will also help extend the transmission distance from around 2,000 kilometers (km) to over 3,000 km and play a key role in integrating remote renewables on a large scale and facilitating a more interconnected grid.

China has major load centers in its eastern region, while a significant amount of its energy resources are in the west and northwest. The expansive geography and increased demand over the last decade have prompted the build-up of UHV capacity to transmit larger amounts of power over greater distances with minimum losses.

Why a new rated UHVDC?
• Meeting increasing energy demands
• Lowering environmental impact
• Renewable energy sources are often located far from load centers
• UHVDC 1,100 kV increases capacity up to 25%, a prodigious upgrade from 800 kV UHVDC
• Even lower transmission losses over long distances

UHVDC is the number one choice when it comes to bringing huge amounts of energy from renewable resources, often far away, to large load centers. China, India, Africa and the Americas are markets with these requirements.

Converter transformers play a critical role in HVDC transmission serving as the vital interface between the DC link and the AC network. Development of the 1,100 kV transformer addressed several technology challenges including the sheer size and scale, as well as bushings and electrical insulation and thermal performance parameters. The transformers will be among the most powerful in the world, meeting the most stringent performance, reliability and safety standards.

Each converter transformer weighs 800 tons and measures 32 meters in length. The 1,100 kV transformers will be manufactured and tested in ABB’s state-of-the-art transformer facility in Ludvika, Sweden.

Key enablers
• Domain expertise of ABB scientists and engineers
• ABB’s top modern test facilities
• Use of advanced simulation tools
• Earlier ABB developments, existing well proven 600 kVdc and 800 kV UHVDC
• In-house manufacturing capability
• 60 years of experience in commercial HVDC technology

Ultra high voltage transformers are among the most powerful in the world.
### ULTRA HIGH VOLTAGE

**DEVELOPMENTS IN POWER TRANSFORMERS TECHNOLOGY**

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### The basics of 1100 kV Converter Transformers

**Meeting increasing energy demands**
- Energy consumption projected to increase by 50% by 2040
- Electricity demand projected to grow by 70% by 2040
- Almost all growth will come in non-OECD countries, more than half from India and China

**Lowering environmental impact and footprint**
- Electric power generation mix moving towards renewables
- Renewable energy sources are often located far from load centers
- Right of Way (RoW) is limited and becoming an environmental permitting issue as well as a cost issue

**Increased power transmission capacity of UHVDC links**
- 1,100 kV UHVDC increases capacity to 12GW which is 50% higher than the 8GW 800kV links in service
- Opens a new voltage level above 800 kV which enables lower transmission losses over even longer distances

**Quick facts about the 1,100 kV technology**
- Rated voltage: 1,100 kV DC
- Rated power: The 1,100kV UHVDC link has a capacity of up to 12000 MW
- Transmission distance: over 3,000 km, which is equivalent to the distance between Barcelona and Moscow
- Each transformer is 32 meters long and weighs over 800 tons, which is equal to approximately 550 average cars
- The UHVDC links are based on LCC technology (Line Commuted Converter) in conjunction with overhead transmission line
- Dielectrics air insulation, thermal and mechanical design were key areas for new concepts/prototypes to be developed

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### Technical challenges

**The major technical challenges during the R&D phase:**
- Extreme insulation requirements for 1,100 kV DC. The challenge to develop the electrical design of full-scale transformers, to know the limitation for insulation design and complete analysis of thermal, magnetic and mechanical properties.
- 750 kV AC line side voltage for sending end meant simultaneous challenges on both AC and DC sides of the transformers
- The very challenging time schedule requirements included the R&D to be completed in less than 18 months

The design, manufacturing and testing of the transformer prototype was completed on schedule and all tests passed according to the customer (SGCC) specification in June 2012. ABB was the only supplier to manage the challenging time schedule. The expertise and experience, combined with a track record of delivered equipment and components to the Chinese market, continues to demonstrate ABB’s leadership in transformer technology and project execution.

**Financial aspects**
- The main aspects to the financial evaluation for 1,100 kV UHVDC transmission line:
  - The investment costs for the line: the installation including the transmission line is cheaper for the client, the power track is minimal and takes significantly less space
  - The power line losses
  - The investment costs for the converter station the R&D to be completed in less than 18 months

**Environmental aspects**
- The 1,100 kV Changji-Guquan UHVDC link enabled increased bulk transmission power with minimum environmental impact for the customers including low CO2 emissions and a small footprint. One UHVDC transmission link could provide power equal to today’s power consumption for about 26.5 million Chinese people.
  - Enabling large scale integration of renewable power resources
  - Narrow tracks, the power line track is minimal which allows more power to be transmitted using less line corridors, which means high efficiency of land resources
  - Lower losses, the losses are significantly lower with HVDC than AC
  - UHVDC can easily satisfy stricter magnetic field requirements and has ultra-low noise levels

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### Capacity equivalent to 8 large power plants

- **So far** 800 kV
  - 8 x 2000 km ~8,000 MW
  - Paris Athens
  - Each transformer = 32 meters long, 800 tons weight

### Capacity equivalent to 12 large power plants

- **Now** 1100 kV (1.1 million Volts)
  - 12 x 3000 km ~12,000 MW
  - Barcelona Moscow
  - 50% Increase
ABB HVDC converter transformers
800 kV UHVDC – Groundbreaking development

World’s first 800 kV UHVDC transformers
• Xiangjiaba-Shanghai 800kV UHVDC
• Capacity to transmit up to 6400 MW of power
• Rated power: 300 MVA
• First technology step since Itaupi 600 kVdc, including development of completely new transformer technology
• Successfully in operation since 2010

ABB power transformers
800 kV/10GW Bushing – Groundbreaking development

World’s first 800kV 10GW bushing
• World’s most powerful transformer bushing, capable of handling 10,000 MW (10 GW) of direct current electrical power rated for 800 kV
• Successfully designed, developed and tested world’s first 800kV 10GW UHVDC transformer wall bushing
• Enables up to 25% higher power transmissions over long distance, compared with the 800kV UHVDC links in current operation

ABB HVDC converter transformers
1,100 kV UHVDC – Groundbreaking development

World’s first 1,100kV transformer
• Successfully designed, developed and tested world’s first 1,100 kV UHVDC transformer prototype with accompanying bushing, in June 2012
• Capacity to transmit up to 12 000 MW (12GW) of power
• Rated power: 600 MVA
• Highest power level ever 12 GW electricity over 3000 kilometers

ABB power transformers
1200kV UHVAC – Groundbreaking development

World’s first 1,200 kV UHVAC transformers
• Bina station, 1,200 kV UHVAC
• World’s most powerful UHVAC power transformers, alternating current electrical power rated for 1,200kVac
• Successfully developed, manufactured and energized 1,200 kV UHVAC transformers
• The transformer was manufactured and tested at ABB’s state-of-the-art Vadodara facility in India
In China and India, the demand for energy is growing dramatically. China installs new power-generating capacity every year.

A major expansion of hydropower will be needed to satisfy this demand. 1100 kV enables transmission of power as far as 3,000 kilometers with reasonable transmission losses. A significant part of the world growth in power transmission capacity will be in China and India.

ABB continues to demonstrate its leadership in transformer technology and project execution, and to develop innovative solutions to serve the existing global installed base.

ABB transformers contribute to grid stability and power reliability, while ensuring the highest safety standards and striving to increase energy efficiency and reduce environmental impact.

Besides setting new records in transformer power ratings, ABB helps customers address new challenges and opportunities like the integration of renewables – shaping the evolution of flexible solutions in a challenging future.