Le Tang, ABB , April 22, 2013

HVDC Technologies & ABB Experience

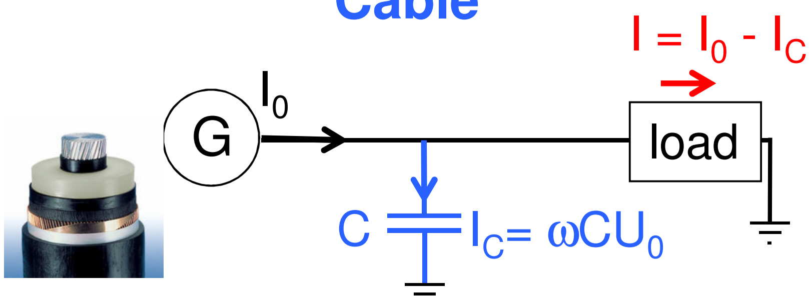
DOE Workshop – Applications for High-Voltage Direct Current Transmission Technologies

Power and productivity
for a better world™

Why is DC important in the Transmission Grid ?

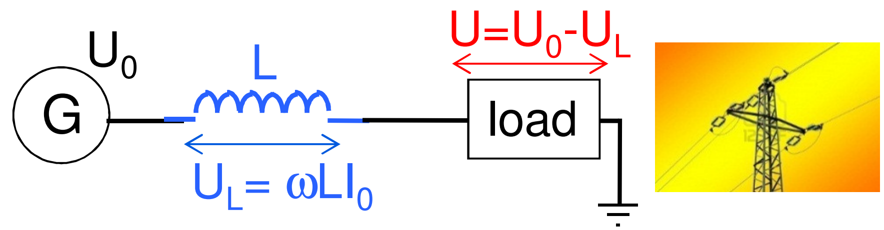
Capacitance and Inductance of Power Line

Cable



In cable > 50 km (>30 miles), most of AC current is needed to charge and discharge the "C" (capacitance) of the cable

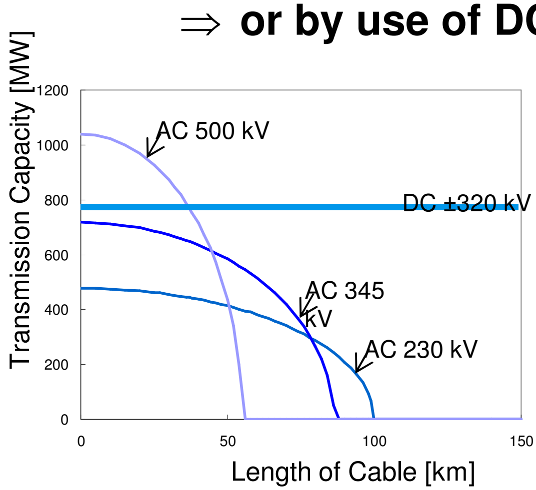
Overhead Line

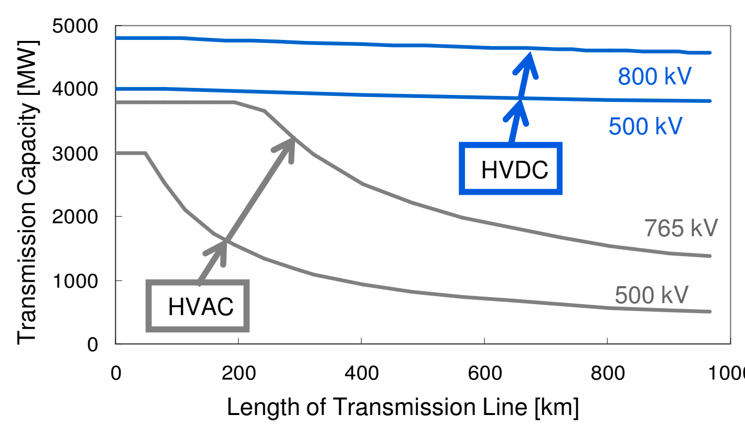


In overhead lines > 200 km (>120 miles), most of AC voltage is needed to overcome the "L" (inductance) of the line

$\Rightarrow$ C& L can be compensated by reactors/capacitors or FACTS

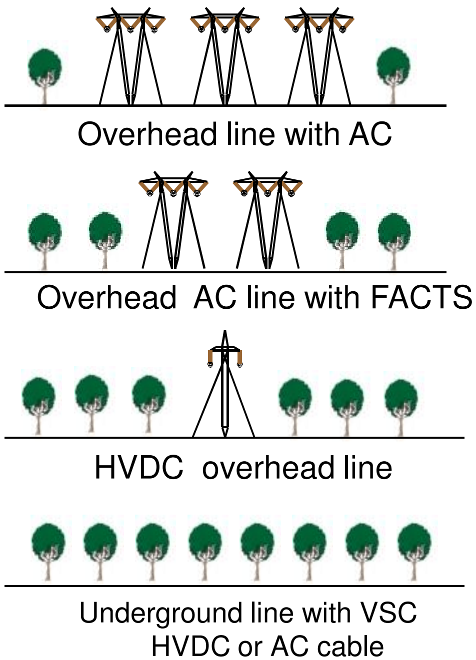
$\Rightarrow$ **or by use of DC, which means $\omega = 2\pi\nu = 0$**



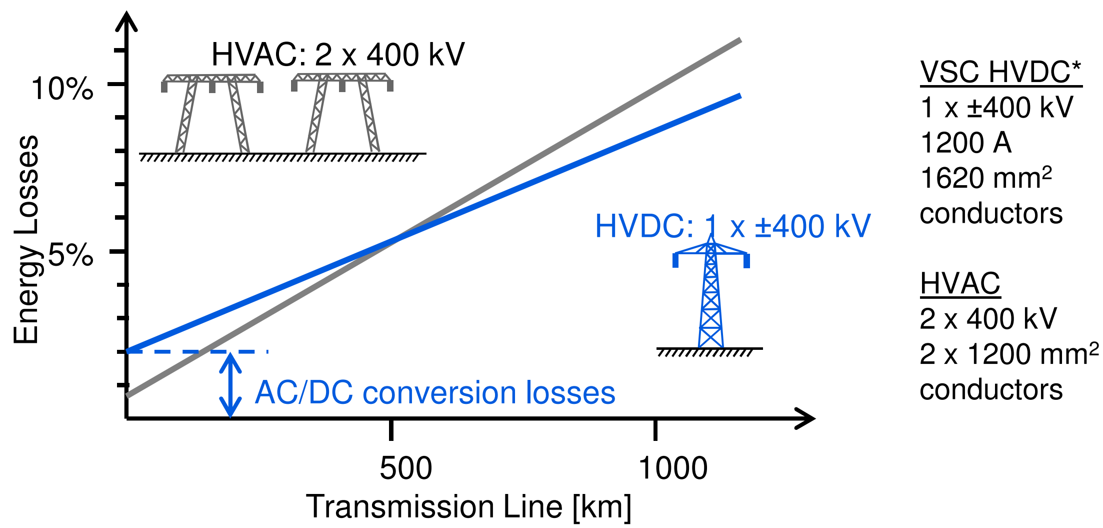


Benefits of HVDC vs. HVAC

Different technologies:
Same power transmitted



- Higher transmission capacity
- Possibility to use underground and subsea cables
- Lower losses on long distances



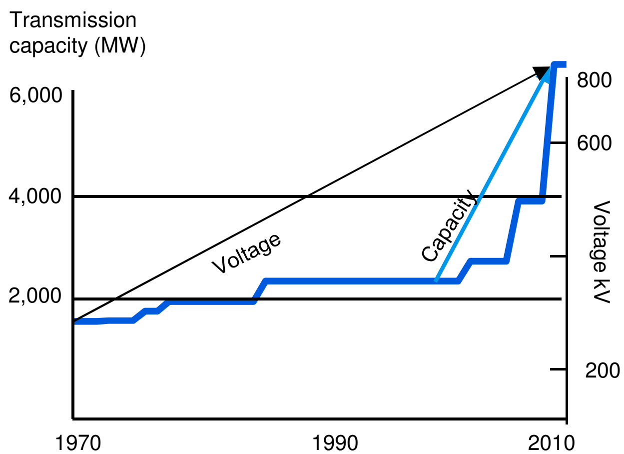
*Voltage Source Converter : High Voltage Direct Current

HVDC technology development
More power and lower losses

HVDC Classic

Capacity up 6 times since 2000; Voltage up from +/- 100kV to +/- 800kV since 1970

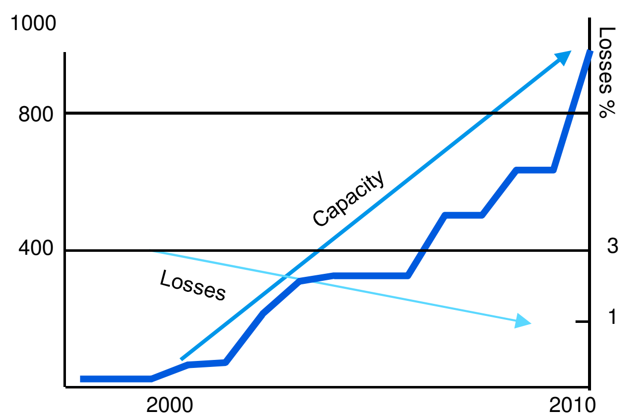
Xiangjiaba - Shanghai
± 800 kV UHVDC. World's most powerful link commissioned



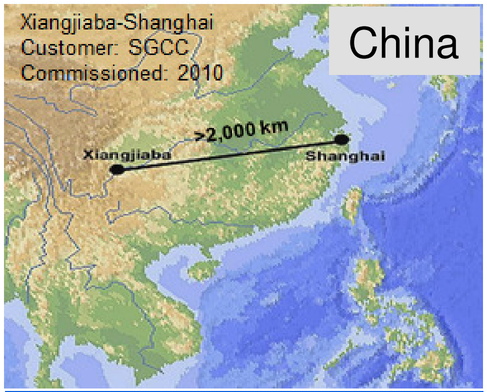
HVDC Light

Capacity up 10 times; losses down from 3% to 1% per converter station since 2000

BorWin:
400 MW, 200km subsea and underground World's most remote offshore wind park



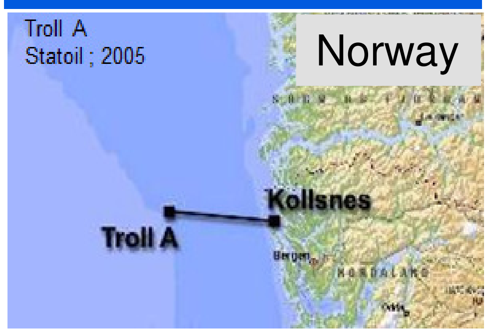
ABB's track record of HVDC innovation
Many firsts – some examples



World's longest / highest power capacity - first 800 kV commercial link -

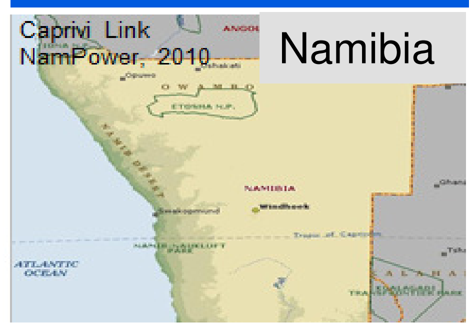
Integrating the world's most remote offshore wind farm

World's longest underwater power link



World's first offshore platform connected to shore power

World's longest underground cable link



World's first HVDC Light on an overhead line

ABB's unique position in HVDC
In-house converters, semiconductors, cables

Key components for HVDC transmission systems

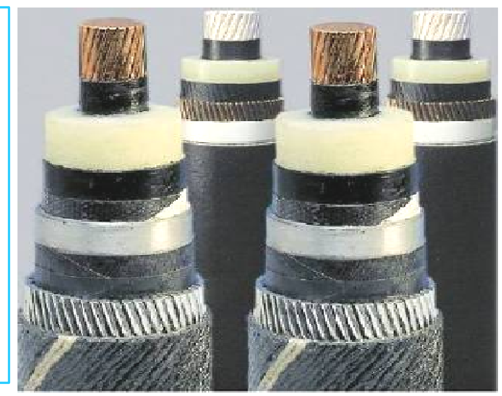
Converters	High power semiconductors	HV Cables
		
		
Conversion of AC to DC and vice versa	Silicon based devices for power switching	Transmit large amounts of power- u/ground & subsea

ABB - Leading Supplier of High Voltage DC Cables
Market Segments

A key enabler for emerging trends

Borwin, Germany integrating the world's most remote offshore wind farm

Offshore Wind farms

Export cables connecting wind farms to land based grid

Troll A, world's first offshore platform connected to shore supply

Offshore Oil and Gas

Export cables from land electrifying offshore platforms

Murraylink, Australia, world's longest underground cable

Undergrounding

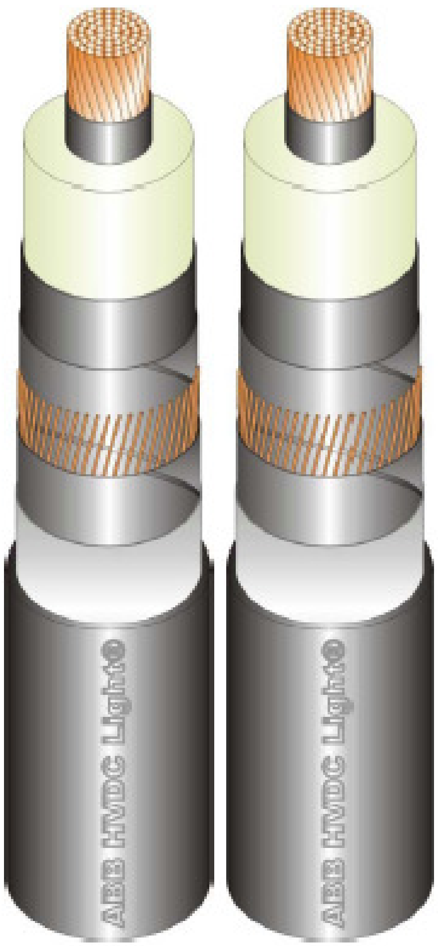
Land cables replacing traditional overhead lines, mainly in and around city centers

BritNed, high-voltage direct-current (HVDC) submarine power cables between UK and NL

Interconnector

Land and sea cables between countries or regions

Solid Dielectric Cables for HVDC transmission



1999
Gotland
160 kV (±80 kV)
50 MW
43 miles

2000
Direct Link
160 kV (±80 kV)
3×60 MW
3×40 miles

2002
Murray Link
300 kV (±150 kV), 220 MW
112 miles

2006
EstLink
300 kV (±150 kV), 350 MW
20 miles (+46 miles subsea)

2009
BorWin
300 kV (±150 kV), 400 MW
47 miles (+80 miles subsea)

2012
EWIP
400 kV (±200 kV), 500 MW
46 miles (+116 miles subsea)

2007-2009
Type and PQ test
2500 mm^2 Cu or Al
640 kV (±320 kV), up to 1100 MW

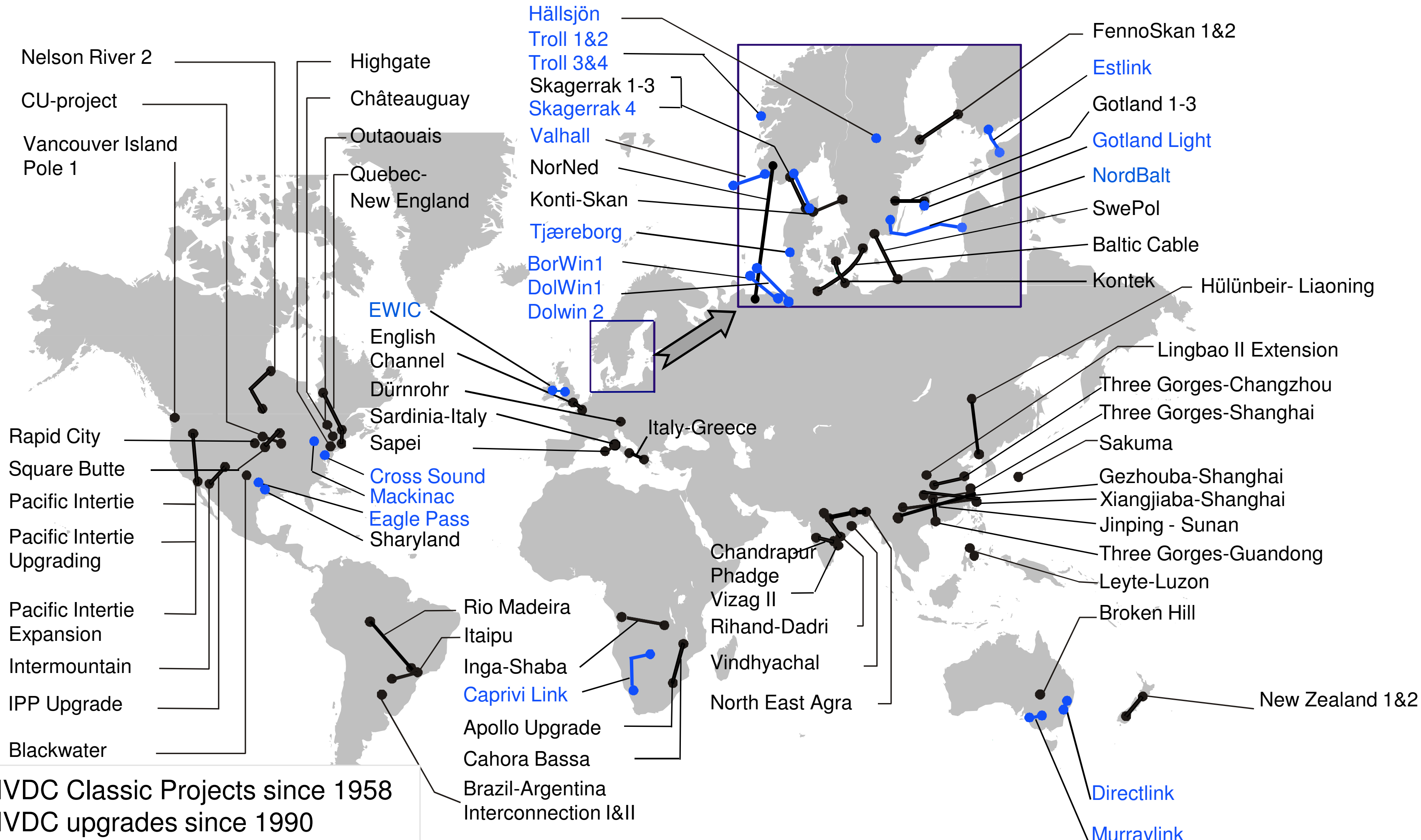
2013
DolWin1
640 kV (±320 kV), 800 MW
60 miles (+47 miles subsea)

2015
NordBalt
600 kV (±300 kV), 700 MW
31 miles (+248 miles subsea)

2015
DolWin 2
640 kV (±320 kV), 900 MW
56 miles (+28 miles subsea)

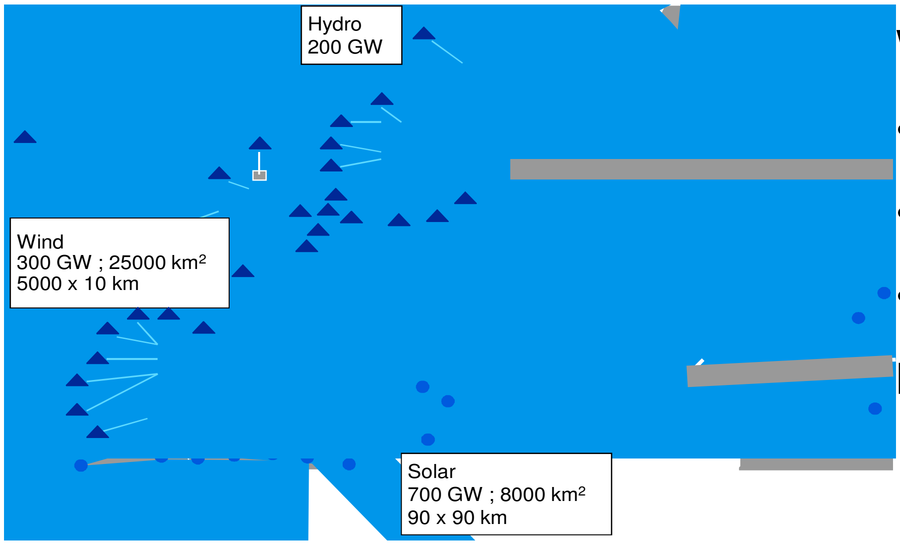
ABB has more than half of the145 HVDC projects

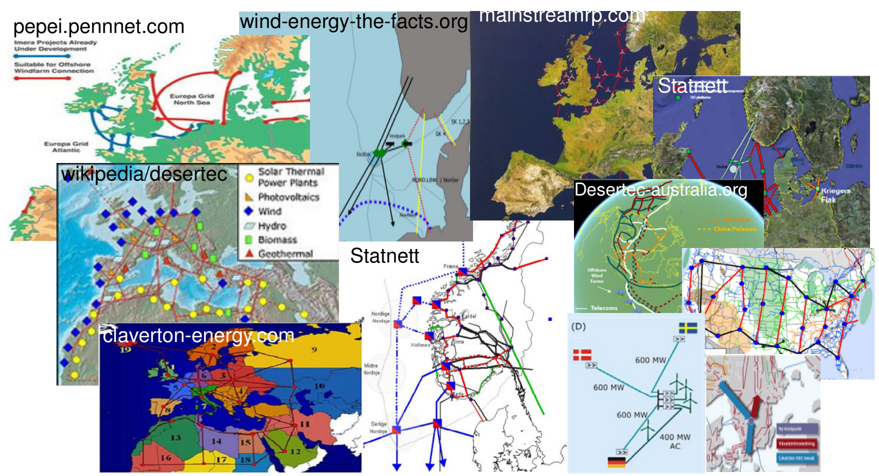
The track record of a global leader



58 HVDC Classic Projects since 1958
14 HVDC upgrades since 1990
19 HVDC Light Projects since 1997

DC grid vision first conceived in 1999
Now a shared vision





Future developments

- Multi-taps / DC grids / Mixed AC/DC grids

Why DC grids vs DC single links

- Optimize investment & system performance
- Need for renewable integration
- Technology advance

How

- From point to point connections to small multi-terminal HVDC and taps to pan-continental HVDC grids

Technology gaps to close

- DC breaker
- Control and protection
- Power flow control
- Cables with higher power ratings

Other gaps to close

- Political consensus/Regulatory framework
- Funding and operation models

HVDC breakers
State of the art technology

R&D – 2 parallel approaches

Option 1 (2011):
Semiconductor Breaker
High losses

Option 2 (2012) :
Hybrid Breaker:
Mechanical + Semiconductor
Lower Losses

500 kV

300 kV

3kV

1kV

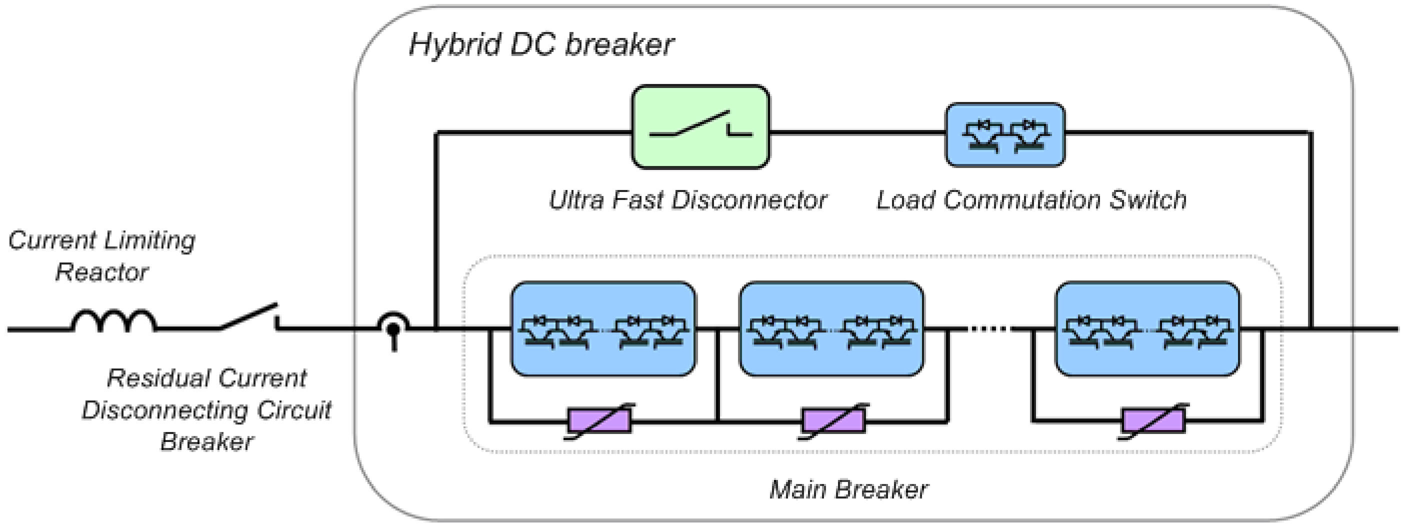
Existing products

LV CB   Traction CB   DC Grid Breakers

Main challenges:
- Energy
- Speed (Short circuit current)
- Losses

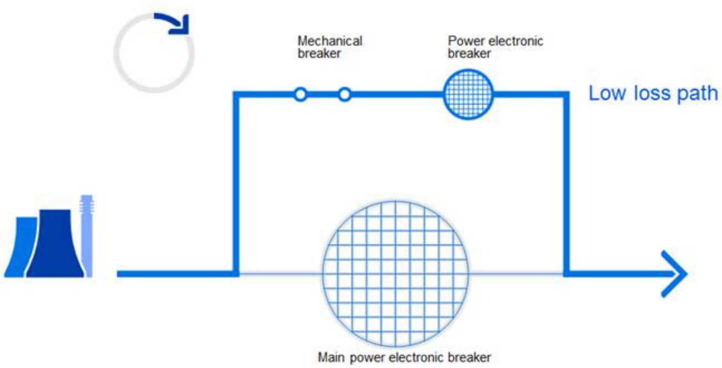
ABB

Hybrid DC Breaker
Basic Design

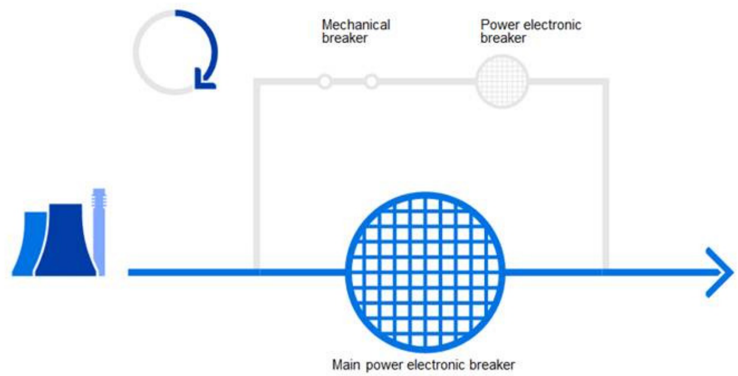


Modular design of Main DC Breaker for improved reliability and enhanced functionality
Fast DC current measurement for control and protection
Disconnecting residual DC current breaker isolate arrester banks after fault clearance

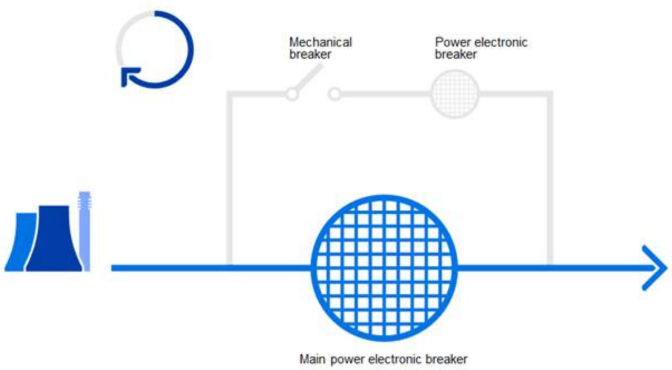
ABB's hybrid HVDC breaker
How it works ?



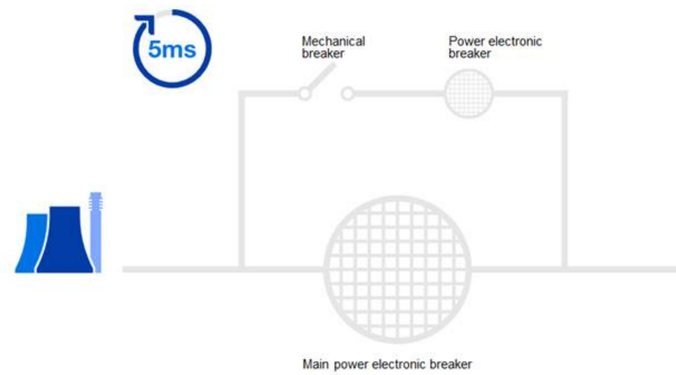
A. Normal operation. Power flow in the path with less resistance (=lower losses)



B. Breaker started by power electronic breaker closing pushing the current flow into the lower path

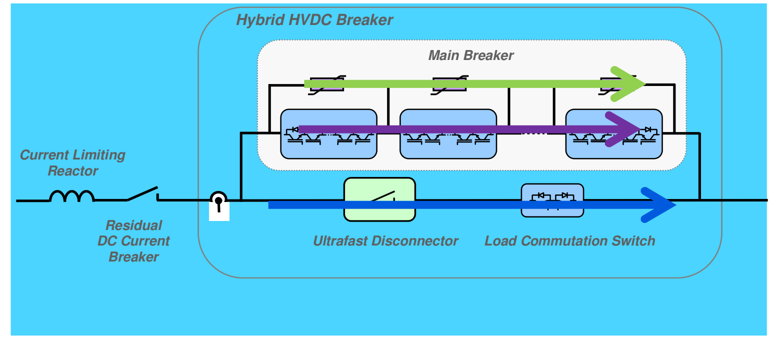


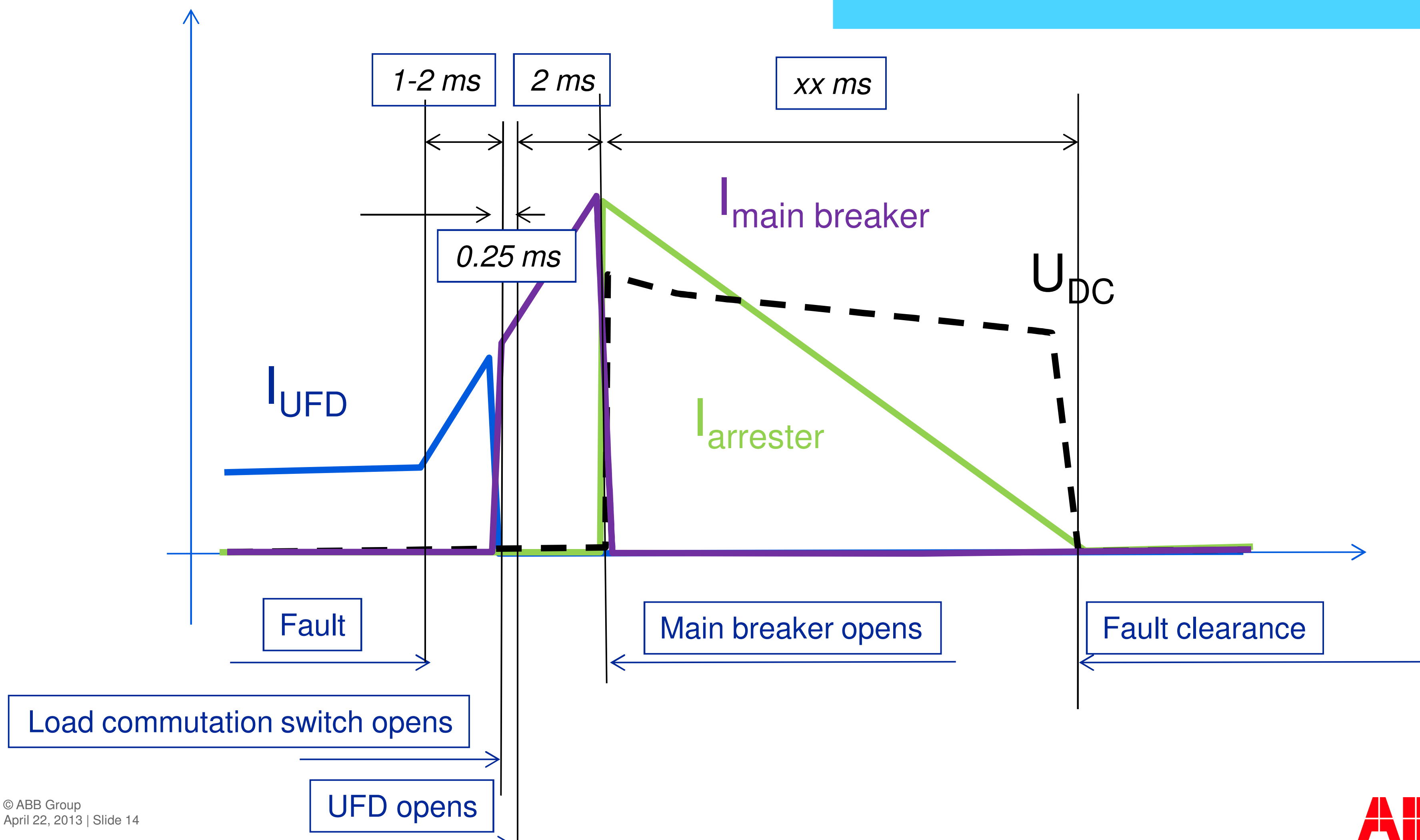
C. Mechanical breaker opens to block the upper path



D. Main electronic breaker block in the lower path

Hybrid HVDC Breaker
Breaking timeline





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