CONVERSATORIO :

Junio 10

Colombia

Sistemas HVDC

SESIÓN 2 :
Operación e impacto de Sistemas HVDC en redes existentes

VSC Based HVDC Application for Integration of Renewables

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Un evento: cigre Colombia | Universidad Pontificia Bolivariana, Vigilada Mineducación, 50 años Ingeniería Electrónica, 70 años Ingeniería Eléctrica | isa CONEXIONES QUE INSPIRAN

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Content

- Renewable Generation : Drivers
- Colombia and Brazil
- Renewable Generation: Challenge for the Grid
- Introduction to VSC
- VSC based HVDC Systems: Special Features
- VSC Installations for Renewable Energy Systems
- Conclusion

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Solar and Wind Power in Europe: Drivers

- EU Renewable Energy Directive (2009/28/EC): final consumption of 20% by 2020
- Revised Renewable Energy Directive (2018/2001): final consumption of 32% for 2030
- Italy, Spain, Portugal
- Spain: Removal of Sun Tax
- Italy: 50 % residential tax reduction
- Move towards subsidy free markets

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How it looks today

COLOMBIA

- Colombia has a renewable power potential estimated in about 20 GW (already mapped)
- Committed power of 2,5 GW (auctioned in 2019) to be in operation in 2022/23
- Planning includes 14 GW installed capacity up to 2033, being 7 GW from La Guajira region
- HVDC is the preferred way to connect renewable generation to the grid

BRAZIL

- 15 GW installed Wind capacity (2019).
- 3,4 GW installed Solar capacity (2019).
- Almost 100% built with private investments as consequence of predictability of profits
- Regulatory agency (ANEEL) has already actioned off new wind and solar farms, reaching 20 GW (wind) and 12,5 GW (solar) by 2023
- Up to now, Brazil has only explored on shore potential, that's estimates 60 GW (wind) and 30 GW (solar) in 2030, meaning 1/3 of Brazilian Energy matrix

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Renewable Generation: Challenge for the Grid

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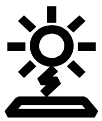
Connection to AC Grid



- Solar PV based generation is non-continuous that require highly advanced features for connection to the AC grid since its
  - variable during day time, dependent on weather conditions and
  - zero power generation after sunset impacting system voltages at point of coupling

- Wind is a continiously varying source of generation
- Advanced features for intergrating wind power to AC grid are needed for maintaing stable voltage profile at point of coupling

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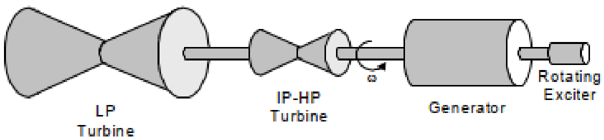
Contribution to System Inertia

- Presence of large synchronous machines provide system inertia offered by the network
- Renewables that include solar PV generation and wind turbines deviate from traditional high mass machines used for thermal and hydro generation
- Zero system inertia by Power Electronic based solar PV generation
- Wind generation is also non-inertia contributing source
  - as wind turbines are not directly connected to the grid and
  - large-scale wind penetration leads to reduced system inertia



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System Stability

- Reduced system inertia has negative impact on grid transient stability
- Power Electronic based generation results in lack of dynamic support to AC network
- Loss of electromechanical inertia influences
  - Rate of change of frequency (ROCOF)
  - System frequency stability

Introduction to Voltage Source Converters (VSC)

Introduction to Voltage Source Converter (VSC)

- 1997, world's first VSC HVDC installation
- Self commutated IGBT and BIGT switches
- Application of installations till date:
  - Interconnecting grids
  - Offshore wind connections
  - Power from shore
  - DC links in AC grids

Salient features

- Frequency decoupling
- Variable RES* integration
- No limitation in circuit length
- Fast control of active and reactive power
- Lower transmission losses
- Black start capability
- Power oscillation damping
- Reduced environmental foot print

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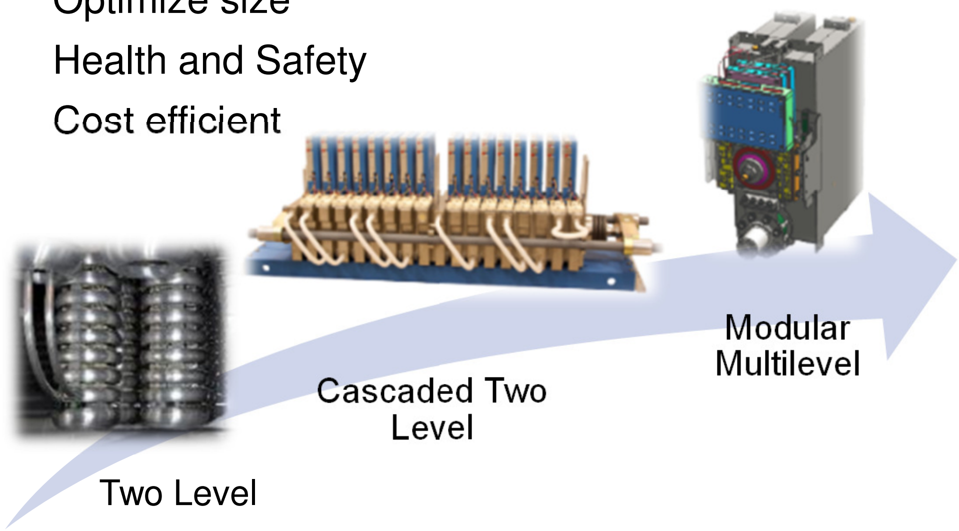
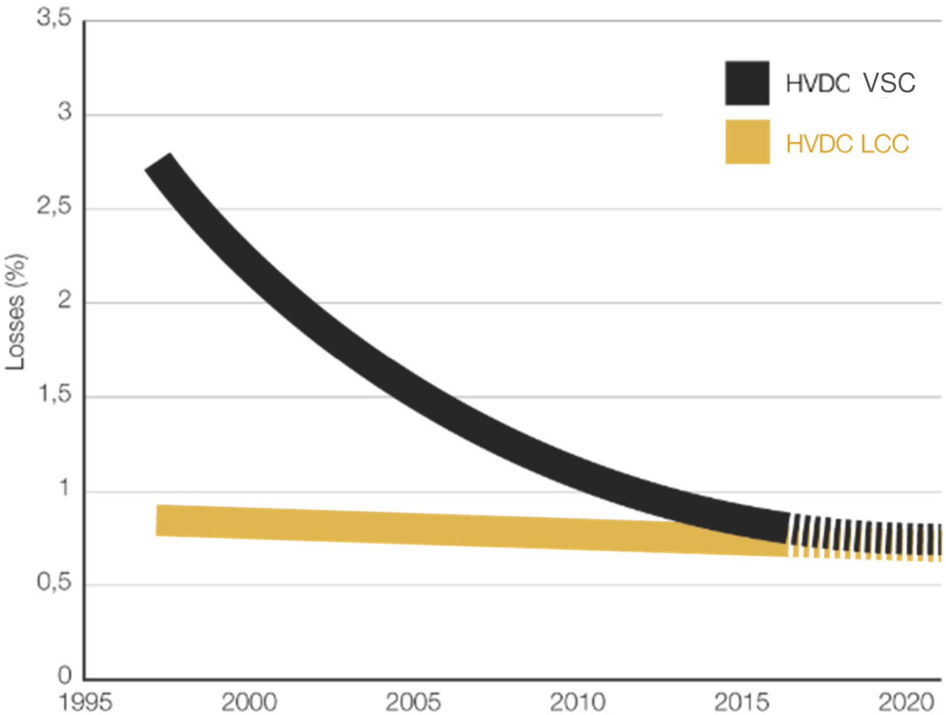
VSC Development

Design objectives

- Lower losses
- Optimize size
- Health and Safety
- Cost efficient





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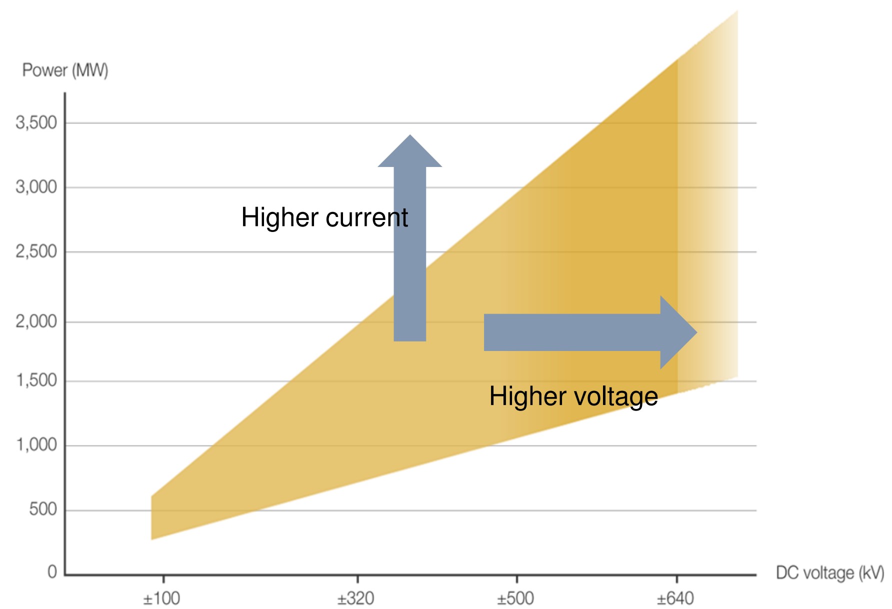
VSC Development

How is it done?

- Increased voltage rating
- Cutting-edge, bi-mode insulated gate transistor (BIGT)
- Optimized switching
- Modular multi-level converter (MMC) technology
- Very low no-load losses



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VSC based HVDC Systems: Special Features for Connection of Renewable Generation

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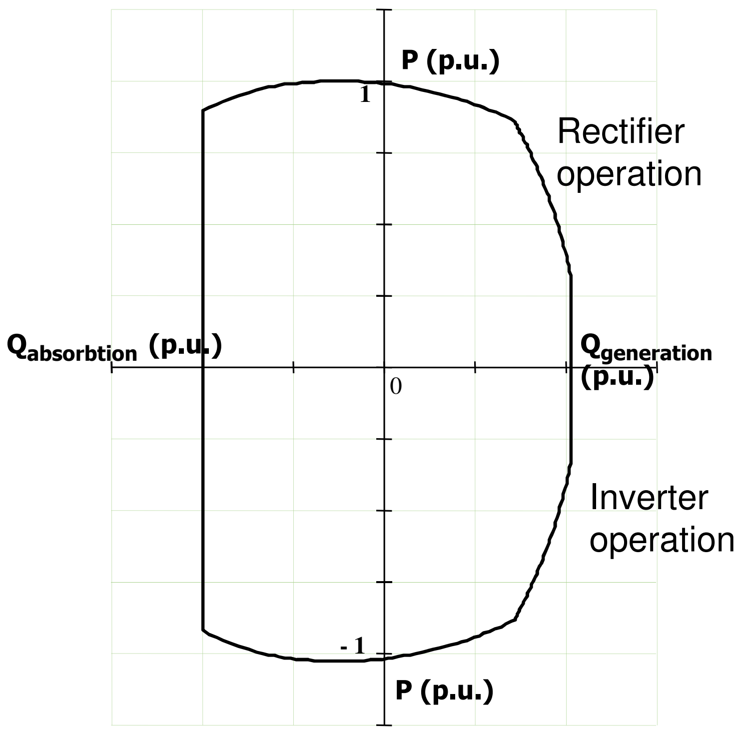
Reactive Power Support



Typical PQ curve for Voltage Source Converter

- Independent active and reactive power control
- Inherent STATCOM mode: integrates variable generation without additional reactive power compensation devices
- Compensates generation fluctuation and stabilizes system voltage
- Continuous reactive power compensation for system voltage variations
- Indefinite operation at zero dc power to provide reactive power support to ac network

Other stability features

- VSC converter acts as firewall against transfer of harmonics or other disturbances to the connecting ac grids
- Blackout in one network will not affect the other ac network

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Connection to Passive Network

- VSC can self-commute without stiff voltage source. Synchronous condensers are not needed for starting or operating the link.
- Significant advantage connecting RES via VSC system as LCC systems are dependent on synchronous condensers of connected ac network to provide commutating voltage for turn-off.
- Black Start feature is offered by VSC converter due this self-commuting ability as the ac network during system blackout is passive.

System restoration: Black Start Capability

- Black Start : ability to restore power of blackout network with help of healthy ac grid
- VSC acts as UPS* in an operating mode called the synchronous machine emulating mode
- Synchronous Machine: controls frequency, voltage and phase of ac voltage while restoring the power by setting it to predetermined reference limits
- VSC: Does it through 'virtual or synthetic' inertia i.e, without the actual inertia that is offered by the large mass synchronous machines

Frequency Control by Virtual Inertia

- AC system: Frequency variations managed by power output of synchronous machines
- VSC Systems: Frequency variations managed by virtual inertia i.e., without machine inertia, but through controls
- Frequency Control Mode: VSC absorbs or supplies active power as per grid requirement and maintains system frequency

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VSC Installations in RES

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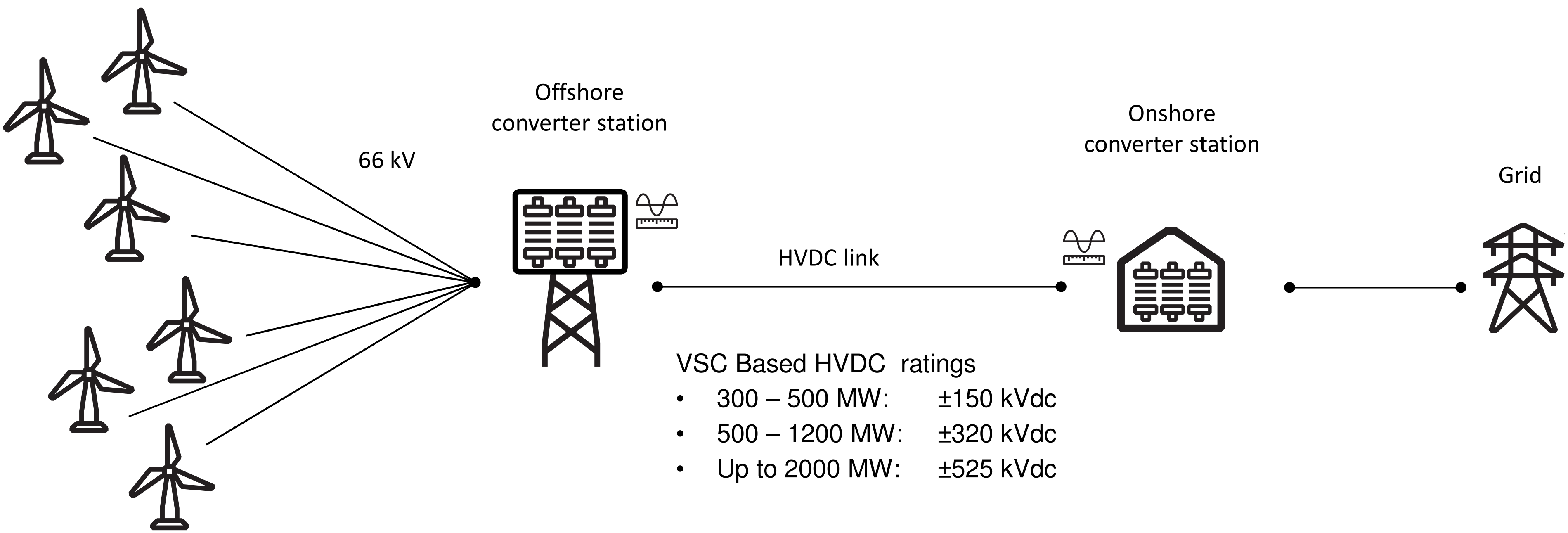
Offshore Wind Connections

Increasing connection capacity



VSC Based HVDC ratings

- 300 – 500 MW: ±150 kVdc
- 500 – 1200 MW: ±320 kVdc
- Up to 2000 MW: ±525 kVdc

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Applications in offshore wind

Borwin 1

Dolwin 1

Dolwin 2

Thornton Bank

Princess Amalia (Q7)

Various projects: equipment supply

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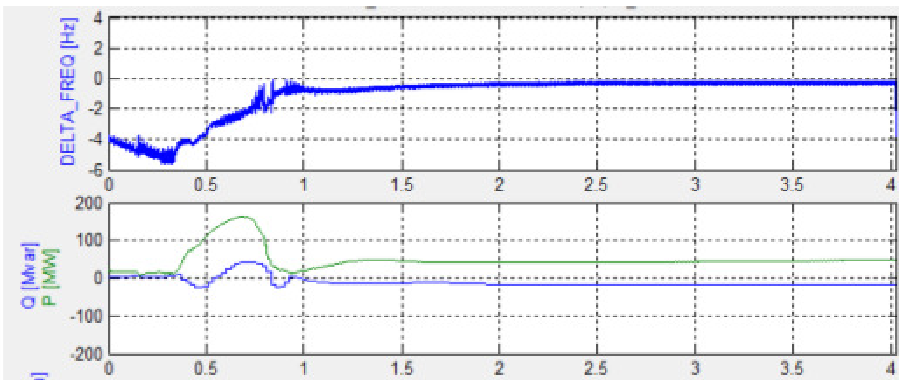
Case Study

Grid Frequency Control

- Reference project*: VSC based HVDC Caprivi Link Interconnector -350kV, 300MW
- Location: Connecting Namibia and Zambia networks in Africa
- Frequency variation within AC network is managed by change in active power injection by HVDC converter



Plot 1: Frequency deviation from nominal frequency
Plot 2: Active power (green), Reactive power (blue)

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Conclusion

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Conclusion

- Future is Power Electronic based renewable generation that offer no physical inertia
- Lack of or reduced inertia is a challenge for operation and stability of future ac grid
- VSC HVDC is proven technology for connection of highly variable renewables like wind
- Offering grid stability with features of
  - independent active and reactive power control
  - virtual inertia
  - STATCOM capability
  - frequency control
  - black start
  - multi-terminal operation
  - lower environmental footprint

Gracias