Lehrveranstaltung
„Umwandlung elektrischer Energie mit Leistungselektronik“

HVDC

(High Voltage Direct Current)
Hochspannungs-Gleichstrom-Übertragung

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State-of-the Art:

**AC Transmission**

usually 3phase 50/60 Hz

simple conversion of voltages and currents
(by magnetic transformers)

magnetic transformers combine high voltage and low voltage conductors without problems

magnetic transformers provide high efficiency (> 95 %)

**AC electricity generation is a mature technology**

Problems:

AC Transmission
usually 3phase 50/60 Hz

interconnection of extended electric grids may result in stability problems (resulting in black-outs etc.)

interconnection of electric grids is only possible when using the same frequency

inductances and capacitances of cables and overhead lines limit the capacity of long-distance power transmission

compensation of reactive power necessary (?)

Trends and Tendencies in Energy Transmission

Reduction of …
… installation space
… transfer losses

Dynamic Controllability of Power Flow

- Environment Protection
- Supply Security
What is HVDC?

What is HVDC?


e.g. realized in Japan to interconnect 50 Hz electrical grid in North Japan with the 60 Hz grid in South Japan.
What is HVDC?

Basic HVDC Transmission
Point to Point – Overhead Line

Rectifier
Transformer
F
F

Inverter
DC Line
Idc
Harmonic Filter (Reactive Power)

Vdc

Idc

lac

Long Distance Transmission
Up to 3000 MW

Source: EPECS 2013, Istanbul, Turkey – Djeahf Mohamed:
Steady-State and Dynamic Performance of Asynchronous Back-to-Back VSC HVDC Link
What is HVDC?

- E.g. realized between Mosambique to interconnect Cabo Basa (Sambesi river) and South Africa
- The power plant in the grid in South Africa
What is HVDC?

... to interconnect off-shore wind parks (e.g. North Sea) with the grid on the continent/mainland.

Many HVDC Systems Worldwide

État de l'art sur le transport d'énergie en courant continu haute tension;

- Réalisations

Why DC transmission?

1. Technical considerations
2. Economic considerations
3. Environmental considerations

Unlike the case for ac cables, there is no physical restriction limiting the distance or power level for HVDC underground or submarine cables.

- No (capacitive) charging currents;
- Control of Power Flow Directly;
- The Power Flow on an HVDC link is Fully Controllable - Fast and Accurate!

Fast controllability of power flow in dc lines eliminates all of the above problems;

- Corona effects tend to be less significant on dc than for ac conductors.
- The absence of skin effect with dc is also beneficial in reducing power losses marginally, and the dielectric losses in case of power cables is also very much less for dc transmission.

A DC link allows power transmission between AC networks with different frequencies or networks, which can not be synchronized, for other reasons.
Why DC transmission?

- Technical considerations
- Economic considerations
- Environmental considerations

**État de l'art sur le transport d'énergie en courant continu haute tension**

- AC tends to be more economical than DC for distances less than the "breakeven distance" but is more expensive for longer distances.

*Fig.* variation of costs of transmission with distance for ac and dc transmission.

Comparative Costs & Losses (by ABB)
(6,000 MW capacity @ 75% utilization)

Source: EPECS 2013, Istanbul, Turkey – Djehaf Mohamed:
Steady-State and Dynamic Performance of Asynchronous Back-to-Back VSC HVDC Link
Why DC transmission?

- Technical considerations
- Economic considerations
- Environmental considerations

Environmental Considerations

Environmental considerations

- The land coverage and the associated right-of-way cost for an HVDC overhead transmission line is not as high as that of an AC line.

- This reduces the visual impact and saves land compensation for new projects.

- It is also possible to increase the power transmission capacity for existing rights of way.

Figure: Deux pylônes de même taille, transportant deux puissances différentes.
Environmental Considerations

État de l’art sur le transport d’énergie en courant continu haute tension;

Right Of Way
Conventional 400 kV AC or new Supergrid with ±800 kV DC?

13 GW transmission capacity
With conventional AC, 400 kV double system

520 m

Or
13 GW transmission capacity
With newest DC, ±800 kV HVDC double bipolar

64 m

Source: EPECS 2013, Istanbul, Turkey – Djeuf Mohamed:
Steady-State and Dynamic Performance of Asynchronous Back-to-Back VSC HVDC Link
existing AC landlines can be used for DC transmission

- with 2x (double) the AC power **without changing anything**
  (same installation of electricity towers and conductors)

- with 4x (!!!) the AC power **without changing the size**
  of the transmission line
  (same installation of electricity towers
   – just new conductors and attachments)

→ there is **no technical need**
   for **new** paths for transmission lines
   for using the North Sea wind power in Southern Germany
Why HVDC?

The land coverage and the associated right-of-way cost for an HVDC overhead transmission line is not as high as that of an AC line.

Less visual Impact,

Possibility of choosing a transmission by cable

HVDC – „ancient“ and modern

Principe de fonctionnement des liaison CCHT

CONVHVDC « LCC »

HVDC PLUS « voltage source converter »

HVDC – „ancient“ and modern

Older HVDC Technology: LCC

HVDC – „ancient“ and modern

Principe de fonctionnement des liaisons HVDC Light

Neutral-point clamped inverter
One phase arm (3 level)

Neutral-point clamped inverter
Three-phase circuit (3 level)

HVDC – „ancient“ and modern

Why VSC HVDC?
Key Benefits Compared to Classical HVDC - 2

- Inherent Black Start capability
  - Always a requirement for offshore wind and island feeding applications

- Compact dimensions and lower weight
  - Ideal for inner cities, reduced visual impact, smaller and lighter offshore platforms

- Power reversal by adjusting the DC voltage at both converter stations
  - Enables the use of low cost polymeric cables
HVDC – „ancient“ and modern

Comparaison entre les liaisons HVDC classiques et HVDC Light

HVDC Light: the clean technology

ausgeführte Anlagen
realized systems
Trans Bay Cable
San Francisco CA, USA

> 5000 IGBTs in Betrieb
Nennleistung: P = 400 MW
Q = ± 170-300 MVAr
Spannungsstützung in Potrero (SF)
Wirkleistung: 400 MW (Dauerbetrieb)
Trans Bay Cable: Erste Multilevel-HGÜ der Welt

- **Motivation:**
  Versorgungslücken im kalifornischen Netz um San Francisco

- **Herausforderung:**
  'Right of way' für neue Freileitungen oder Erdkabel

- **Lösung:**
  Seekabel durch die Bay von San Francisco

- **Weitere Herausforderung:**
  Benötigte Grundstücksgröße für HVDC Classic

- **VSC HVDC:**
  Geringerer Platzbedarf
Trans Bay Cable
San Francisco CA, USA
**INELFE (1st Generation)**
Netzverbindung Frankreich – Spanien

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<tr>
<th>Customer</th>
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<td>Transmission dist.</td>
<td>appr. 60 km</td>
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INELFE - Netzverbindung Frankreich – Spanien

Santa Liogaia Station (Spanien)

Baixas Station (Frankreich)
Offshore Windparks der Nordsee
Übersicht der anzubindenden Windparks
BorWin2 – Warnemünde, Plattform (Offshore)
Aufbau der Plattform
Offshore Grid Access

HelWin I: ± 250 kV / 576 MW
HelWin II: ± 320 kV / 690 MW
BorWin II: ± 300 kV / 800 MW
BorWin III: ± 320 kV / 900 MW
SylWin I: ± 320 kV / 864 MW

Helwin 1:
- ± 250kV; 576 MW ≈ 500,000 Haushalte
- Fläche: 75 m x 50 m
- Höhe: 23 m – 7 Decks
- Gewicht: 12,000 t
- Das Baseframe wird mit bis zu 100 Meter langen Pfeilern in der dort 23 Meter tiefen Nordsee verankert
BorWin2 – Diele, Landstation (Onshore) 
Baufortschritt

Vogelperspektive – Januar 2012 (ca. 9 Monate nach Auftragsvergabe)
Conclusions

- Judicious use of HVDC can stabilize an AC system

- HVDC is a complement to a well-designed AC network

- In this presentation we have presented the steady-state and dynamic performances of VSC based back-to-back HVDC transmission system during step changes of the active and reactive powers, balanced and unbalanced faults.

- The system advantages of deploying a VSC based B2B asynchronous Tie with standby dynamic voltage control during network contingencies. The controlled power transfer capability allows the exchange of power between the two networks with different frequencies (50/60 Hz).