Energy Transmission in the DESERTEC Project

presented by
Oliver Roth
Matr. No.: 859812

Source: Re-Inventing Construction (2011)
Source: Utilities-ME.com (2012)
Agenda

- How to transport the Energy?
- DESERTEC as a Role Model
- Today’s Grids in Europe & MENA
- The Challenge
- (U)HVDC-, 3-Phase HVAC- & Hydrogen-Transmission
- The Energy Highway
- Energy Security
- Conclusion
How to transport the Energy?

Source: DESERTEC Foundation (2012)
DESERTEC as a Role Model

≈ 90% of the Earth's population lives < 3000 km away from deserts

Source: Map: Informap Technology Center (2012); Information: Franz Trieb (2009)
Today’s Grids in Europe & MENA

Europe

Source: DLR (2006)
Today’s Grids in Europe & MENA

Europe

- very dense network of high voltage power lines
- in wide parts of the European energy transmission network 380 kV is the highest voltage level
- in other countries (e.g. Russia) voltages of 500 kV, 750 kV & even 1200 kV for long distance transmission
- **problem:** very less connections between the countries (e.g. Germany and France) → “bottlenecks”
- a cable already connects Spain & Morocco (Strait of Gibraltar) opened in 1997 → so far electricity flows predominantly from Spain to North Africa

Source: DLR (2006); Rat für Nachhaltige Entwicklung (2012)
Today's Grids in MENA & Europe

Middle East & North Africa

- electricity grid much less dense than in Europe
- concentrated to the coastal regions and the Nile valley
- interconnects only between Egypt, Jordan & Syria and Algeria, Morocco & Tunisia
- Lybia connected with Tunisia since 2003 → not yet synchronized

Source: DLR (2006); Werrenfels / Westphal (2010)
The Challenges of DESERTEC

- functioning interconnections required: e.g.
  - Tunisia → Italy &
  - Turkey → Greece
    → MedRing

- new “transmission lines”
  - through North Africa → Mediterranean Sea (ca. 1000 km)
  - through Italy (ca. 1000 km) → to Central Europe (ca. 1000 km)
    → about 3000 km

- transmission costs shall NOT to a too high electricity price (!!!!!!!)

Source: DESERTEC Foundation (2012)

Source: DLR (2006); Heckmann (2010)
3-Phase HVAC-Transmission

Source: GeVestor Financial Publishing Group (2012)
3-Phase HVAC-Transmission

High Voltage Alternating Current Transmission

- based on conventional 3-phase alternating current
- in Europe frequency of 50 Hz

Source: Benz (2010); DLR (2006); Heckmann (2010)
3-Phase HVAC-Transmission

**Advantages:**
- transformability (between voltage levels)
- generation by simple electro-mechanical energy conversion
- frequency can be used for system control
- mashing easily possible

**Disadvantages:**
- transmission capacity limited by inductive and capacitive parameters (reactive power)
  - high losses (6-8 % losses per 1000 km)
  - long distance transmission limited
- cables limited to very short distances

Source: Benz (2010); DLR (2006); Heckmann (2010)
(U)HVDC-Transmission
(Ultra) High Voltage Direct Current Transmission

- voltage $\geq 800$ kV $\rightarrow$ UHVDC
- direct current (const.) flows in one direction
- generation: electrochemical processes or rectification of alternating current

Source: DLR (2006); ABB (2012a); Benz (2010); Siemens AG (2011b)
(U)HVDC-Transmission

Advantages:

- transmission capacity not limited by inductive and capacitive parameters
  - low losses (3-5 % losses per 1000 km)
  - long distance transmission possible
  - cables can be placed in the underground
    - higher acceptance of the population
  - very stable

- allows power transmission between AC networks with different frequencies or voltage levels

Source: Benz (2010); Siemens AG (2011a); Siemens AG (2012)
(U)HVDC-Transmission

- less masts / lines needed
  - lower costs of transmission lines
  - little area demand (60% of HVAC)
  - small ecological footprint

**Disadvantages:**

- high fix costs for transformer / converter stations

⇒ HVDC interesting for longer distances

Source: Benz (2010); Siemens AG (2011a); Siemens AG (2012)
## Costs of UHVDC & HVAC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>HVAC</th>
<th>(U)HVDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation Voltage</td>
<td>kV</td>
<td>750</td>
<td>1150</td>
</tr>
<tr>
<td>overhead line losses</td>
<td>%/1000 km</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>sea cable losses</td>
<td>%/100 km</td>
<td>60%</td>
<td>50%</td>
</tr>
<tr>
<td>terminal losses</td>
<td>%/station</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>overhead line cost</td>
<td>M€/1000 km</td>
<td>400 – 750</td>
<td>1000</td>
</tr>
<tr>
<td>sea cable cost</td>
<td>M€/1000 km</td>
<td>3200</td>
<td>5600</td>
</tr>
<tr>
<td>terminal cost</td>
<td>M€/station</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: Universität Bonn (2010)

### Break-Even Distance
- **AC Line**
- **AC Terminal**
- **DC Line**
- **DC Terminal**

**Source:**
- own design (concept: Dan (2012))
(U)HVDC-Transmission

UHVDC Projects in Europe & Asia

Xiangjiaba–Shanghai (China)

Source: Benz (2010)

Source: Benz (2010)

Technical Data

<table>
<thead>
<tr>
<th>Customer</th>
<th>State Grid Corporation of China and XD Xi’an Power Rectifier Works (XPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name</td>
<td>Xiangjiaba</td>
</tr>
<tr>
<td>Location</td>
<td>Xiangjiaba–Shanghai</td>
</tr>
<tr>
<td>Power rating</td>
<td>6,400 MW, bipolar</td>
</tr>
<tr>
<td>Type of plant</td>
<td>Long-distance transmission, 2070 km</td>
</tr>
<tr>
<td>Voltage levels</td>
<td>±800 kV DC, 525 kV AC, 50 Hz</td>
</tr>
</tbody>
</table>

Source: Siemens AG (2011b)
Hydrogen-Transmission

Idea:

- production of hydrogen from water by using the produced el. energy (mostly in deserts)
- transmission and distribution of the hydrogen by pipelines like conventional energy carriers fuel oil and natural gas → well known technology and existing networks
- direct hydrogen utilisation e.g. as fuel in fuel cell driven automobiles

Source: DLR (2006); DESERTEC Foundation (2012)
Source: HybridCars.com (2012)
Hydrogen-Transmission

BUT:

- there is **NO water available in most of the deserts!!!!**
- 50 % energy demand & losses for the conversion process
- pumping losses (transport to Europe (ca. 3000 km))

![Graph showing energy transmission efficiencies](image)

- Transmission by UHVDC → 90 % Efficiency
- Transmission by HVAC → 60 % Efficiency
- Transmission by hydrogen → 25 % Efficiency

Source: DLR (2006); DESERTEC Foundation (2012)
The Energy Highway

Concept

- electrical energy generated in regions of best performance
  - distributed all over Europe and MENA by **highly efficient HVDC grid ("Super Grid")**
  - supply of consumers by the conventional interconnected AC grid (lower voltage level)

- transport of the energy to storage places (e.g. pump storage power plants in Norway, Austria and the Switzerland)

Source: DESERTEC Foundation (2012); saena (2012); Deutschlandfunk (2012)
The Energy Highway

Concept

- more and more fluctuating regenerative energy resources (PV, wind, ...)
  - stabilisation of the large electricity grids
  - “UHVDC backbone”

Targets for 2050:

- 20 - 40 transmission lines from the MENA region to Europe
- lines deliver 15 % of the European energy demand
  - ca. 700 TWh/y
### The Energy Highway

#### Costs (TRANS-CSP Study (DLR))

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Capacity GW</td>
<td>2 x 5</td>
<td>8 x 5</td>
<td>14 x 5</td>
<td>20 x 5</td>
</tr>
<tr>
<td>Electricity Transfer TWh/y</td>
<td>60</td>
<td>230</td>
<td>470</td>
<td>700</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>0.60</td>
<td>0.67</td>
<td>0.75</td>
<td>0.80</td>
</tr>
<tr>
<td>Turnover Billion €/y</td>
<td>3.8</td>
<td>12.5</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>Land Area km x km CSP</td>
<td>15 x 15</td>
<td>30 x 30</td>
<td>40 x 40</td>
<td>50 x 50</td>
</tr>
<tr>
<td>Land Area km x km HVDC</td>
<td>3100 x 0.1</td>
<td>3600 x 0.4</td>
<td>3600 x 0.7</td>
<td>3600 x 1.0</td>
</tr>
<tr>
<td>Investment Bilion €</td>
<td>42</td>
<td>143</td>
<td>245</td>
<td>350</td>
</tr>
<tr>
<td>Investment Bilion €</td>
<td>5</td>
<td>20</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td>Elec. Cost €/kWh CSP</td>
<td>0.050</td>
<td>0.045</td>
<td>0.040</td>
<td>0.040</td>
</tr>
<tr>
<td>Elec. Cost €/kWh HVDC</td>
<td>0.014</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Source: DESERTEC Foundation (2009)

Transmission costs: 1.0 – 1.4 €-ct/kWh
The Energy Highway

Possible Organisation Structures

Financing usually by transmission system operators (TSOs) of the both connected countries

→ high investment costs (impossible for some TSOs)
  ➔ European financing instruments (?)

→ no experience with ownership structures for electrical transmission grids bypassing several countries
  ➔ organisation similar to that of gas pipelines (?)

→ e.g. Nabucco pipeline
  “Nabucco Gas Pipeline International GmbH”
  (planning, financing, construction, marketing & maintenance)
Excursus: Planning an Electric Grid

Electric grids cannot be built everywhere!!!

Excluded Areas:

- protected areas
- industrial areas
- populated places
- deep sea areas
- geomorphologic features
- etc.

Source: DLR (2009)
Energy Security

What about terroristic attacks?

→ 20 – 40 planned interconnections between MENA & Europe

→ dense electricity grid can compensate outage of several lines

→ **highly secure against attacks**

Can the produced energy be used as political leverage?

→ coal, oil, natural gas & uranium can be kept back today and sold tomorrow

→ electric energy (today) not!!!

→ earnings would be irrevocably lost

→ **high interest of suppliers to secure energy supply**

Source: DESERTEC Foundation (2012); Deutsche Gesellschaft CLUB of ROME e.V. (2011)
Conclusion

Source: DESERTEC Foundation (2012)
Thank you for your Interest!
References

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