Long Distance Subsea Power Transmission and Distribution

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Parameters used

• Power ~30MW

• Voltage ~110kV

• Distances up to 600km offshore

• Water depths to 1500m
Technology Options

- **AC (3 phase)**

- **DC**

  - Resultant DC waveform
Technology Options

High Voltage Alternating Current - HVAC (50Hz)

- Onshore: LVAC 50Hz
- Subsea: HVAC 50Hz, LVAC 50Hz

Diagram:
- Generator
- Transformer LV / HV
- Transformer HV / LV
- Subsea Load
Technology Options

Low Frequency High Voltage Alternating Current - LFHVAC (16\(\frac{2}{3}\)Hz)

Onshore

LVAC 50Hz

Generator
Transformer
LV / HV

Transformer
Frequency
Converter

Subsea

LFHVAC 16\(\frac{2}{3}\)Hz

Frequency
Converter

Transformer
HV / LV

Subsea Load

LVAC 50Hz
Technology Options

High Voltage Direct Current - HVDC

Onshore

LVAC 50Hz

Generator
Transformer
LV / HV

AC / DC Converter

Subsea

HVDC

DC / AC Converter

Transformer Subsea
HV / LV

Load

Subsea

LVAC 50Hz

Transformer

Load

AC / DC Converter
Technology Options

High Voltage Direct Current - HVDC

Onshore

LVAC 50Hz

Generator Transformer
LV / HV

AC / DC Converter

Subsea

HVDC

DC / AC Converter

Transformer HV / LV

Subsea Load

LVAC 50Hz
Cable Options

HVDAC & LFHVAC  HVDC Single Core  HVDC Coaxial

Images courtesy of Nexans
Typical Distance Limitations

Longest 730km due 2021
## Typical Cost Comparison

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>HVAC cable cost</th>
<th>LFHVAC cable cost</th>
<th>HVAC terminal costs</th>
<th>LFHVAC terminal costs</th>
<th>HVDC cable cost</th>
<th>HVDC terminal costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>500</td>
<td>200</td>
<td>100</td>
<td>50</td>
<td>800</td>
<td>400</td>
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<td>200</td>
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<td>400</td>
<td>200</td>
<td>100</td>
<td>1600</td>
<td>800</td>
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<tr>
<td>300</td>
<td>2000</td>
<td>600</td>
<td>300</td>
<td>150</td>
<td>2400</td>
<td>1200</td>
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</tbody>
</table>

- **HVAC**
- **LFHVAC**
- **HVDC**
## Qualified Technology

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
<th>HVAC</th>
<th>LFHVAC</th>
<th>HVDC</th>
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<tbody>
<tr>
<td><strong>Cable</strong></td>
<td>Static</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Dynamic</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td><strong>Shore equipment</strong></td>
<td>Generator</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Transformer</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Converter</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Subsea equipment</strong></td>
<td>Transformer</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Converter</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Variable Speed Drives</td>
<td>✗*</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Power Conditioning</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
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<tr>
<td></td>
<td>Connectors</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
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</table>
## Advantages / Disadvantages

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>Conventional subsea cable technology</td>
<td>Cable electrical losses &gt; 100km</td>
</tr>
<tr>
<td></td>
<td>Conventional topside hardware technology</td>
<td>Most subsea hardware not qualified</td>
</tr>
<tr>
<td></td>
<td>Lowest hardware costs</td>
<td></td>
</tr>
<tr>
<td>LFHVAC</td>
<td>Conventional subsea cable technology</td>
<td>Cable electrical losses &gt; 300km</td>
</tr>
<tr>
<td></td>
<td>Conventional topside hardware technology</td>
<td>No qualified subsea hardware technology</td>
</tr>
<tr>
<td></td>
<td>Lower cable electrical losses compared to HVAC</td>
<td>Higher hardware costs &gt; HVAC</td>
</tr>
<tr>
<td>HVDC</td>
<td>Conventional subsea static cable technology</td>
<td>Subsea dynamic cable not qualified</td>
</tr>
<tr>
<td></td>
<td>Conventional topside hardware technology</td>
<td>No qualified subsea hardware technology</td>
</tr>
<tr>
<td></td>
<td>Lowest cable electrical losses</td>
<td>Highest hardware costs &gt; LFHVAC</td>
</tr>
</tbody>
</table>
HVAC Power Transmission <50km
HVAC >50km, LFHVAC & HVDC Power Transmission

Generation

Transformer

Power conditioning and control capsule

Subsea Load
HVAC, LFHVAC and HVDC Power Transmission

Diagram showing subsea power transmission and distribution system:
- Generation
- Sea Level
- Power conditioning and control buoy
- Seabed
- Subsea Load
Summary

HVAC < 150km
LFHVC > 150km < 300km
HVDC > 300km < 600km