Evolutions des liaisons HVDC en technologie VSC : le projet INELFE
Agenda

- Inelfe project outline
- Basics of VSC Technology
  - History & Evolution
  - Features and Benefits
  - Key Components
- Siemens References & Experiences
### INELFE Project outline

**Customer** | INELFE (RTE and REE)
---|---
**Project Name** | INELFE
**Location** | Baixas, France - Santa Llogaia, Spain
**Power Rating** | 2 x 1000 MW
**Type of Plant** | HVDC PLUS
**Voltage Levels** | ± 320 kV DC
| AC 400 kV, 50 Hz
**Distance** | 65 km underground cable
**Semiconductors** | IGBT

![Image of the INELFE project](image.png)

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INELFE
Project outline
INELFE Project
Background of electrical need

- Only 4 interconnections between France and Spain
- Transmission capability is very limited (approx 1200 MW)
- Latest line commissioned in 1982
- Iberic peninsula is almost an electric island (only 3% interconnection capability)
INELFE Project
Reason for choosing DC instead of AC

- Project considered since the 90’s

- Strong social opposition to a 400 kV overhead project

- Decision in 2008 to go to a fully buried project, with tunnel below Pyrénéans

- Due to project length (65 km), DC is the only technical solution for underground connection
INELFE project
Main technical choices

Solution with two parallel links and four (4) cables

Scope of Turn Key
SIEMENS

Baixas
G ~
400kVAC

320kVDC

Santa Llogaia
G ~
400kVAC
INELFE
View of Baixas substation (2000 MW capacity)
Agenda

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## Basics of VSC Technology

<table>
<thead>
<tr>
<th>IFA 2000</th>
<th>INELFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDC Conventionnel</td>
<td>HVDC PLUS</td>
</tr>
<tr>
<td>LCC converters</td>
<td>VSC converters</td>
</tr>
</tbody>
</table>

- **Thyristors** (turn-on only)
- **IGBTs** (turn-on and turn-off)
Additional Features and Benefits of HVDC PLUS

- Grid Access of weak AC Networks
- Independent Control of Active and Reactive power
- Supply of passive Networks and Black Start Capability
- High dynamic Performance
- Low Space Requirements
Space requirements
IFA 2000 / Baixas Substation
HVDC PLUS
The Evolution of HVDC PLUS and VSC Technology

<table>
<thead>
<tr>
<th>Two-Level</th>
<th>Topology of VSC</th>
<th>Three-Level</th>
<th>Multilevel</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Two-Level Diagram" /></td>
<td><img src="image2" alt="Topo Diagram" /></td>
<td><img src="image3" alt="Three-Level Diagram" /></td>
<td><img src="image4" alt="Multilevel Diagram" /></td>
</tr>
</tbody>
</table>

- **Two-Level**
  - Voltage: $V_{ac}$
  - Voltage Levels: $\frac{V_d}{2}$

- **Three-Level**
  - Voltage: $V_{ac}$
  - Voltage Levels: $\frac{V_d}{2}$

- **Multilevel**
  - Voltage: $V_{ac}$
  - Voltage Levels: $\frac{V_d}{2}$

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HVDC PLUS
Modular Multilevel Converter - MMC

- Low level of harmonics and HF noise
- Low switching losses
- Modular arrangement with identical two-terminal power modules
<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Modularity in Hardware and Software</td>
<td>High Flexibility, economical from low to high Power Ratings</td>
</tr>
<tr>
<td>Low Generation of Harmonics</td>
<td>Only small or even no Filters required</td>
</tr>
<tr>
<td>Low Switching Frequency of Semiconductors</td>
<td>Low Converter Losses</td>
</tr>
<tr>
<td>Use of well-proven Standard Components</td>
<td>High Availability of State-of-the-Art Components</td>
</tr>
<tr>
<td>Sinus shaped AC Voltage Waveforms</td>
<td>Use of standard AC Transformers</td>
</tr>
<tr>
<td>Easy Scalability</td>
<td>Low Engineering Efforts, Power Range up to 1000 MW</td>
</tr>
<tr>
<td>Reduced Number of Primary Components</td>
<td>High Reliability, low Maintenance Requirements</td>
</tr>
<tr>
<td>Low Rate of Rise of Currents even during Faults</td>
<td>Robust System</td>
</tr>
</tbody>
</table>
Main components of converter station

- Standard transformers
- Connexion to AC substation
- Converter hall
- DC cable
Main components
Power Module Modular Design

The Power Module
- a two terminal component

Capacitor Unit

The Power Electronics

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Main components
Converter module

- Compact Design
- Modular Design
- Lower Space Requirements
- Advanced VSC Technology
- Maintenance friendly
Main components
Options for Converter Modules and Building Arrangements

A highly flexible Design
Main components

Converter Hall - Example
Main components
Control and Protection System Hierarchy

Operator Level
- Remote HMI
- Local HMI
- SCADA Interface
- SIMATIC WinCC

C&P Level
- SIMATIC TDC
- PLUSCONTROL
- CCS

I/O Level
- I/O Unit
- Measuring
- I/O Unit
- Voltages and Currents
- Converter – Power Modules

SIMATIC TD
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HVDC PLUS (VSC technology)– Made by Siemens
Our References

- SylWin1
- BorWin2
- HelWin1
- HelWin2

- 2010 Trans Bay Cable
- 2013-2015
- 2014 INELFE
HVDC PLUS – Trans Bay Cable Project Overview

<table>
<thead>
<tr>
<th>Customer</th>
<th>Trans Bay Cable LLC</th>
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<tbody>
<tr>
<td>Project Name</td>
<td>Trans Bay Cable Project</td>
</tr>
<tr>
<td>Location</td>
<td>Pittsburg, CA</td>
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<tr>
<td></td>
<td>San Francisco, CA</td>
</tr>
<tr>
<td>Power Rating</td>
<td>400 MW</td>
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<tr>
<td>Type of Plant</td>
<td>HVDC PLUS</td>
</tr>
<tr>
<td>Voltage Levels</td>
<td>± 200 kV DC</td>
</tr>
<tr>
<td></td>
<td>230 kV/138 kV AC, 60 Hz</td>
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<tr>
<td>Semiconductors</td>
<td>IGBT</td>
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<tr>
<td>Cable Supplier</td>
<td>Prysmian</td>
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<tr>
<td>Cable Voltage</td>
<td>± 200 kV</td>
</tr>
<tr>
<td>Cable Type</td>
<td>XLPE</td>
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<tr>
<td>Max. Depth</td>
<td>50 m</td>
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<tr>
<td>Cable Distance</td>
<td>85 km Submarine Cable</td>
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</tbody>
</table>

Customer: Trans Bay Cable LLC
Project Name: Trans Bay Cable Project
Location: Pittsburg, CA, San Francisco, CA
Power Rating: 400 MW
Type of Plant: HVDC PLUS
Voltage Levels: ± 200 kV DC, 230 kV/138 kV AC, 60 Hz
Semiconductors: IGBT
Cable Supplier: Prysmian
Cable Voltage: ± 200 kV
Cable Type: XLPE
Max. Depth: 50 m
Cable Distance: 85 km Submarine Cable
SylWin1, Germany  
World’s 1st Off-shore VSC with 864 MW MMC

<table>
<thead>
<tr>
<th>Customer</th>
<th>Tennet</th>
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<tbody>
<tr>
<td>Project Name</td>
<td>SylWin1</td>
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<tr>
<td>Location</td>
<td>Büttel, Germany</td>
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<tr>
<td>Power Rating</td>
<td>864 MW</td>
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<td>Type of Plant</td>
<td>205 km HVDC PLUS On-/Offshore Cable</td>
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<td>Voltage Levels</td>
<td>± 320 kV DC</td>
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<tr>
<td></td>
<td>155 kV / 300 kV / 380 kV AC, 50 Hz</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>IGBT</td>
</tr>
</tbody>
</table>

![SylWin1, Germany](image)

World’s 1st Off-shore VSC with 864 MW MMC

![SylWin1, Germany](image)
### HVDC PLUS: Evolution of Performances

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Power (MW)</th>
<th>Voltage Level (kV DC)</th>
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<tbody>
<tr>
<td>Transbay</td>
<td>2010</td>
<td>400</td>
<td>± 200</td>
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<tr>
<td></td>
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<td>BorWin 2</td>
<td>2013</td>
<td>800</td>
<td>± 300</td>
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<tr>
<td>Inelfe</td>
<td>2014</td>
<td>2*1000</td>
<td>± 320</td>
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</tbody>
</table>

- Toward more power per link
- Full flexibility for voltage level
Future evolution of VSC technology
The EU supergrid