Power System with VSC-HVDC Interconnection

Frequency Stability Control Strategy

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GEIRI: Global Energy Interconnection Research Institute

Main Working Areas

- Offshore windfarm grid connection
- Offshore HVDC platform design
- Interconnection researches
- Participating research projects, i.e. Horizon 2020, Schaufenster Projects, BMWI Projects etc.
1GW 320kV VSC
Contents

- Introduction: VSC-HVDC connections
- VSC-HVDC structure and controller
- VSC-HVDC connected OWF frequency control
  - Control strategy
  - Simulation results
- VSC-HVDC interconnector frequency control
  - Control strategy
  - Simulation results
- Conclusion and future works
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1. Voltage balancing control
2. Circulating current control
3. Protections
VSC HVDC Controller
Inner Controller

\[ i_d + (KP + \frac{K_I}{s}) = \hat{i}_d \]

\[ i_q + (\omega L) = \hat{i}_q \]

\[ v_{gd} + v_{Q} = \hat{v}_{d} \]

\[ v_{gq} + v_{Q} = \hat{v}_{q} \]
- Voltage frequency control (Vf-control)
- DC-Voltage and AC voltage/reactive power control (Vdc-Vac-control)
- Active power control (P-control)
- Droop control (Droop, for multi-terminal operation)
V/f Controller
Vdc/Vac Controller

\[ \hat{v}_{dc} + \frac{K_P + K_I}{s} \rightarrow i_d \]

\[ \hat{v}_{ac} + \frac{K_P + K_I}{s} \rightarrow i_q \]
VSC HVDC Interconnection

- RG Continental Europe (UCTE)
- RG Nordic
- RG United Kingdom
- RG Ireland
- RG Baltic
OWF VSC-HVDC

- OWF

- Inter-connection
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OWF

- Offshore converter
- ±320kV DC cable
- Onshore converter
- 400kV transmission line
- Onshore power system

Vf-control

Vdc-Vac Control
Frequency Controller
\[ P_{DC} - P_{AC} = C \cdot V_{DC} \cdot \frac{dV_{DC}}{dt} \]
- **OWF**

  ![Diagram of OWF](image)

  - OWF
  - Offshore converter
  - Onshore converter
  - 150kV AC cable
  - ±320kV DC cable
  - 400kV transmission line
  - Onshore power system

  **Trigger**
  
  **PI Controller**
  
  **Gradient Limiter**

  - $V_{DC}$
  - $V_{DC_{ref}}$
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OWF

150kV AC cable

Offshore converter

±320kV DC cable

Onshore converter

400kV transmission line

Load A 500MW

Onshore power system
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![Diagram of power system components and active power generation graphs.](image)

Diagram showing:
- Offshore wind farm (OWF)
- 150kV AC cable
- Offshore converter
- ±320kV DC cable
- Onshore converter
- 400kV transmission line
- Onshore power system

Active power generation graphs:
- Time (s) from 0 to 20, Active power generation from 0.4 to 1.1
- OWF active power (pu) from 0 to 1
Introduction: VSC-HVDC connections

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Conclusion and future works
**OWF**

- OWF
  - 150kV AC cable
  - Offshore converter
  - ±320kV DC cable
  - Onshore converter
  - 400kV transmission line
  - Onshore power system

**Inter-connection**

- Onshore power system A
- 400kV transmission line
- Converter A
- ±320kV DC cable
- Converter B
- 400kV transmission line
- Onshore power system B
**Inter-connection**

- Onshore power system A
- 400kV transmission line
- Converter A
- ±320kV DC cable
- Converter B
- 400kV transmission line
- Onshore power system B

**P-control Frequency Controller**

**Vdc-Vac Control**

\[ f_{ref} \]

\[ f_A \]
Interconnection

Onshore power system A

400kV transmission line

Converter A

±320kV DC cable

Converter B

400kV transmission line

Onshore power system B

P-control

Vdc-Vac
Control
Frequency Controller

Trigger

PI Controller

Gradient Limiter

$V_{DC}$

$V_{DC_{ref}}$
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Conclusion and future works
P Control

- Interconnection

Onshore power system A

400kV transmission line

Converter A

±320kV DC cable

Converter B

400kV transmission line

Onshore power system B

Load A 500MW

Graphs:

- Frequency (p.u.)
- Power (MW)
VDC Control

- Interconnection

\[ \begin{align*}
\text{Onshore power system A} & \quad \text{Converter A} \quad \text{±320kV DC cable} \quad \text{Converter B} \quad \text{400kV transmission line} \\
\text{400kV transmission line} & \quad \text{Load A 500MW} \\
\text{Onshore power system B} &
\end{align*} \]
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Conclusion

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Future works

- Coordinated control: OWF, VSC-HVDC and onshore controllers
- VSC-HVDC voltage stability control
- VSC-HVDC oscillation stability control
- …
Thank you very much for your attention!