Kriegers Flak Grid-Connection System: Automatic Voltage and Reactive Power Control

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ENERGINET – Transmission System Operator of Denmark

Nordic Clean Energy Week, May 21-25 2018, Copenhagen-Malmö
Baltic Offshore Grid Forum
Kriegers Flak Project

• Grid-connection of 600 MW offshore wind power at Kriegers Flak in the Baltic Sea to the 400kV transmission grid of Denmark.

• Interconnection to Germany via the German offshore infrastructure.

• Utilization of the established grid-connection equipment and new equipment for the interconnection between the two countries – Combined Grid Solution.

• Holds the status of a Project of Common Interests by the European Commission.

• Financial support from the European Energy Programme for Recovery (EEPR).

https://youtu.be/wsuQaf-msaE
Kriegers Flak Grid-connection Project

- Grid-connection of 600 MW offshore wind power to East Denmark.
- Two grid-connection points: Bjæverskov (BJS 400kV) and Ishøj (ISH 400kV), and one new compensation substation Bjæverskov (BJS 220kV) onshore.
- Two 220kV offshore platforms: KFB 400MW and KFA 200 MW offshore wind power.
- A 220kV meshed grid-connection system.
- A 400kV onshore grid reinforcement.
- Must be in operation by Dec. 2018.
Single-line diagram

Meshed 220kV system:
• 220kV submarine and land cables forming a meshed HVAC system.
• Single-busbar 220kV substations KFA and KFB (offshore platforms).
• A double-busbar 220kV substation BJS 220kV.
Single-line diagram and Assets of Control

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Assets of the AVR/RPC control:
• 500 MVA 400/220kV transformers TA1 and TA2, and TA3 offshore transformer.
• 120 Mvar 220kV switcheable reactor RKFA.
• 120 Mvar 220kV switcheable reactor RA2.
• 60...120 Mvar 220kV variable reactors RA1, RA3, RA4.
Basic control of n-0 regime

220kV voltage control:
- Target voltage of KFB and KFA platforms.
- Tap-position controllers of TA1 and TA2.
- Master-follow.

Diagram of the control system with voltage levels and connections.
Basic control of n-0 regime

220kV voltage control:
- Target voltage of KFB and KFA platforms.
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- Master-follow.

400/220kV reactive power control:
- Target reactive-power exchange of Ishøj and Bjæverskov.
- Tap-position and switch controllers of RA1, RA2, RA3, and RA4.
- Going into voltage control in excessive voltage in BJS 220kV.
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150kV voltage control:
• Tap-position controller of TA3.
Several n-1 regimes

Among n-1 regimes of the AVR/RPC control:

- A 220kV cable outage.
- A 400/220kV transformer outage.
- BJS 220kV separation.
- Full separation.
- Separation from 150kV infrastructure.
- KFB island.
- KFA and KFB island.
Interconnected n-1 regimes

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Full separation: Cross-coupling detection

- Connection between onshore transformers and offshore platforms through the double-busbar system.

- Connection between reactors and the 400kV grid-connection points through the double-busbar system.

- Preparedness for separate operation.
Separate n-1 regimes

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Power flow patterns

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But the Kriegers Flak grid is special. The power transport can go with or without wind and both directions.

For the AVR/RPC control this means that it works with different voltage profiles and varying reactive power conditions.
Secure and robust control

The point is not how many n-M and power flow patterns we may define.

The point is how to conduct the AVR/RPC control in each of those operation regimes in secure and robust manners.
Simulation normal n-0 operation

Preconditions: 24 hours, 1 minute resolution, wind power fluctuation
Closer look at n-0

Number of steps over 24 h: TA1/TA2: 1/1. RL: 0/0/0/0. VSR: 48/35/6.
Simulation transitions \((n-0) \rightarrow (n-1) \rightarrow (n-0)\)

### Preconditions
- 15 hours, 1 minute resolution
- Wind power fluctuation

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**Active Power MW**

<table>
<thead>
<tr>
<th>Time h</th>
<th>BJS-400-220-autotrf Total Active Power/HV-Side in MW</th>
<th>ISH-400-220-autotrf Total Active Power/HV-Side in MW</th>
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**Transformer Tap Position**

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<thead>
<tr>
<th>Time h</th>
<th>BJS-400-220-autotrf Tap 1, Current Position</th>
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**Reactive Power Mvar**

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<tr>
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<th>BJS-400-220-autotrf Total Reactive Power/HV-Side in Mvar</th>
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**Logic_RL_Dsl Total steps of QL RL7**

- Separate BJS
- Reclose BJS

**Logic_RL_Dsl Total steps of QM RL4**

- Separate KFA-KFB
- Reclose KFA-KFB

**Logic_RL_Dsl Total steps of QM RL6**

- Separate BJS
- Reclose BJS

**Logic_RL_Dsl Total steps of QM RL8**

- Separate KFA-KFB
- Reclose KFA-KFB

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May 23 2018
Number of steps over 15 h: TA1/TA2: 6/4. RL: 0/0/0/3. VSR: 44/36/5.
Conclusion

- **Automatic** voltage and reactive power control (AVR/RPC) due to the system complexity.
- The AVR/RPC complies with reactive-power and voltage ranges.
- Secure and robust control in several operation regimes and flow patterns.
- Most AVR/RPC control-activations are expected in n-1 regimes and (reactive) power flow fluctuations over the interconnector.
- More experience to be gained during the trial operation.
Thank you!

Learn more at:

https://en.energinet.dk/Infrastructure-Projects/Projektliste/KriegersFlakCGS

https://en.energinet.dk/Infrastructure-Projects/Projektliste/KriegersFlakAC