

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

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ENERGINET – Transmission System Operator of Denmark

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Baltic Offshore Grid Forum*

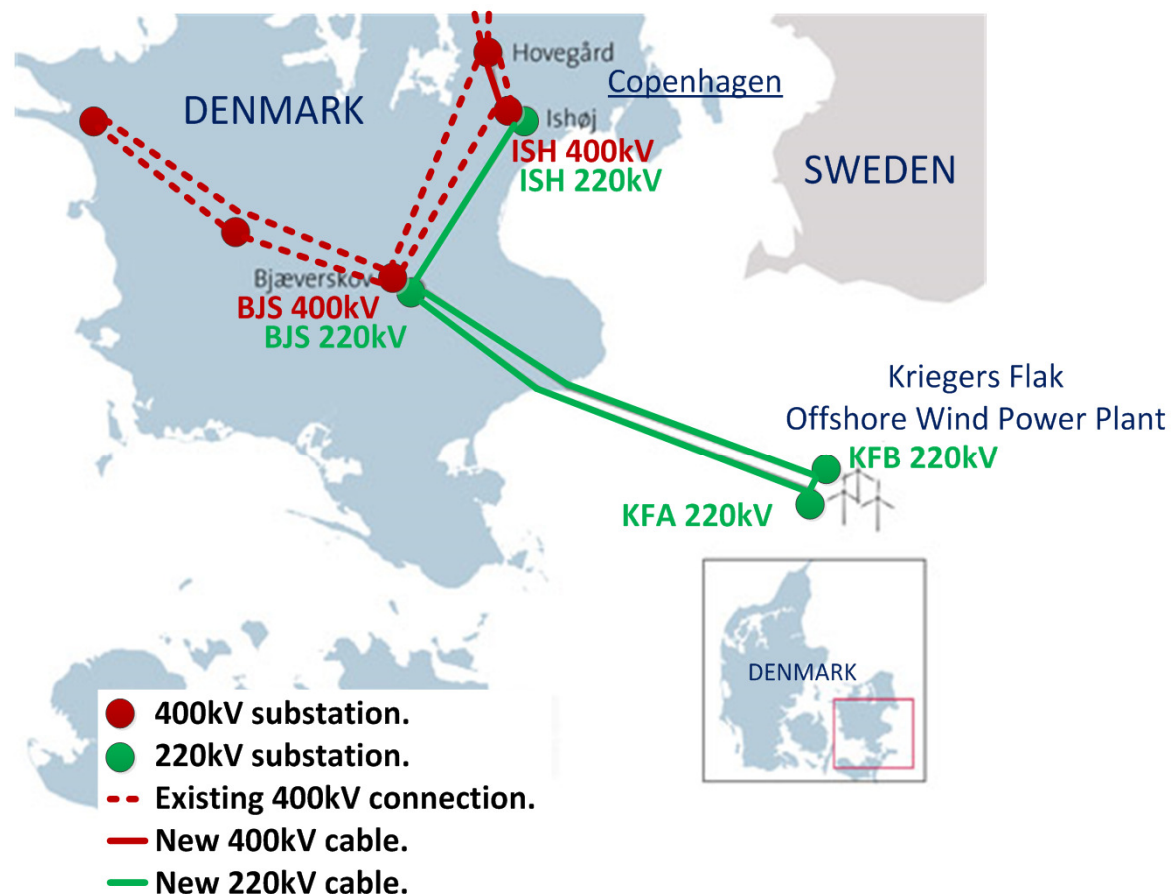
Kriegers Flak Project

- 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

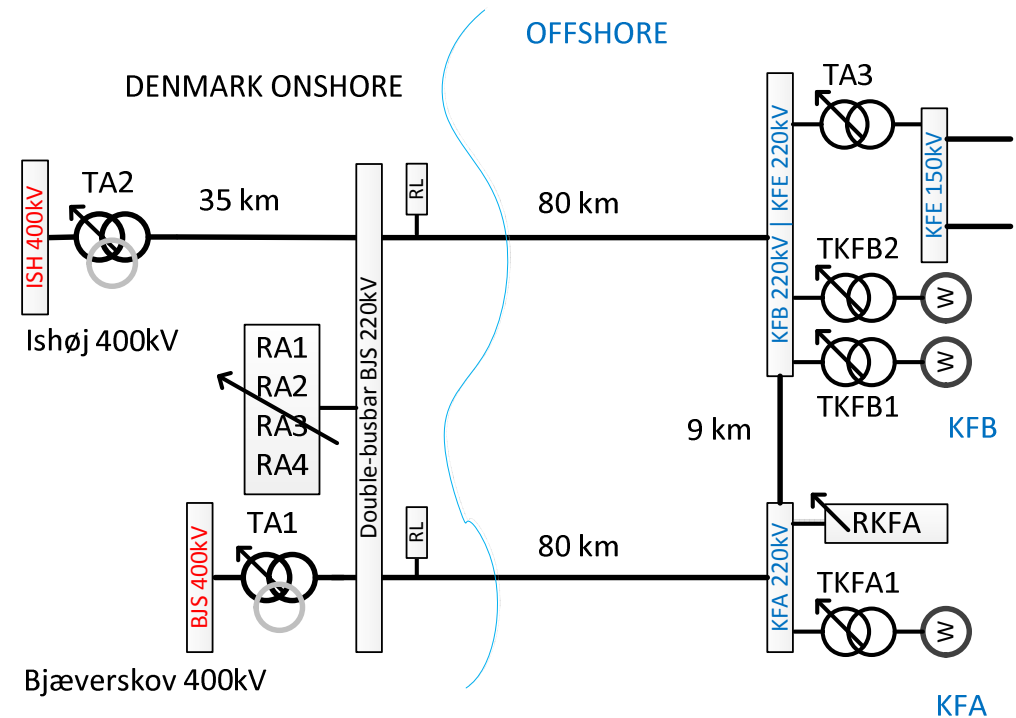
- Grid-connection of 600 MW offshore wind power to East Denmark.
- Two grid-connection points: Bjæverskov (BJS 400kV) and Ishøj (ISH 400kV), and one new compensation substation Bjæverskov (BJS 220kV) onshore.
- Two 220kV offshore platforms: KFB 400MW and KFA 200 MW offshore wind power.
- A 220kV meshed 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.



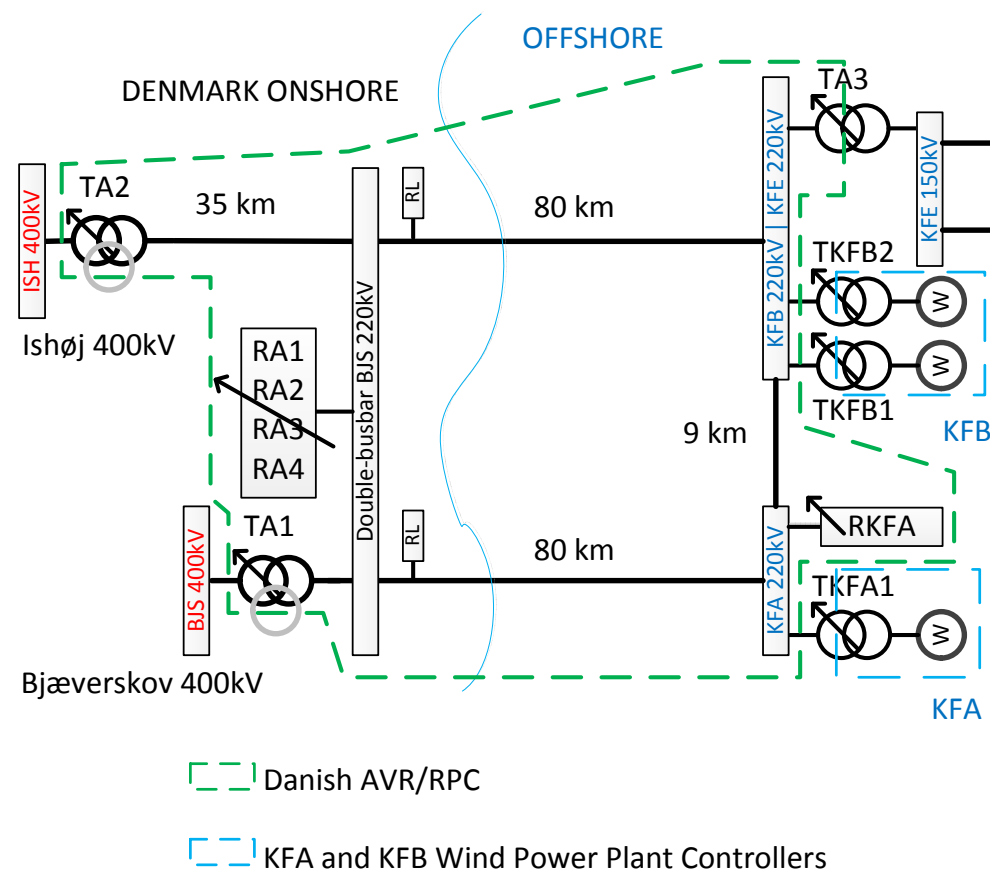
Single-line diagram and Assets of Control

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- 220kV submarine and land cables forming a meshed HVAC system.
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Assets of the AVR/RPC control:

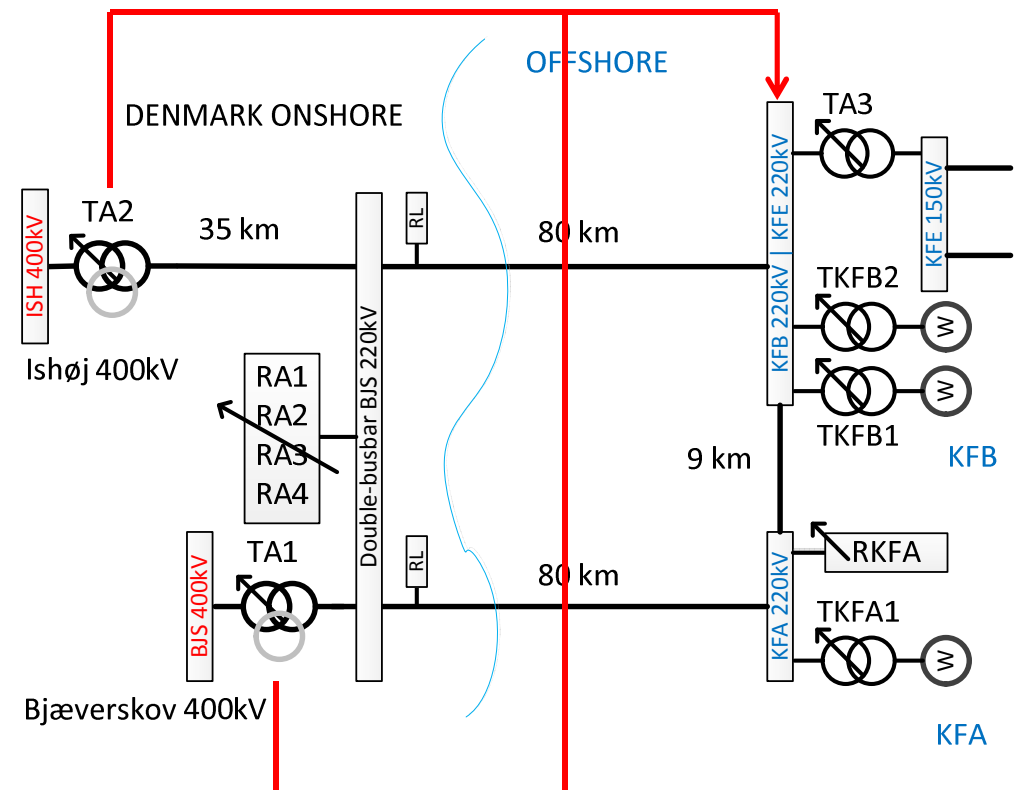
- 500 MVA 400/220kV transformers TA1 and TA2, and TA3 offshore transformer.
- 120 Mvar 220kV switchable reactor RKFA.
- 120 Mvar 220kV switchable reactor RA2.
- 60...120 Mvar 220kV variable reactors RA1, RA3, RA4.



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.



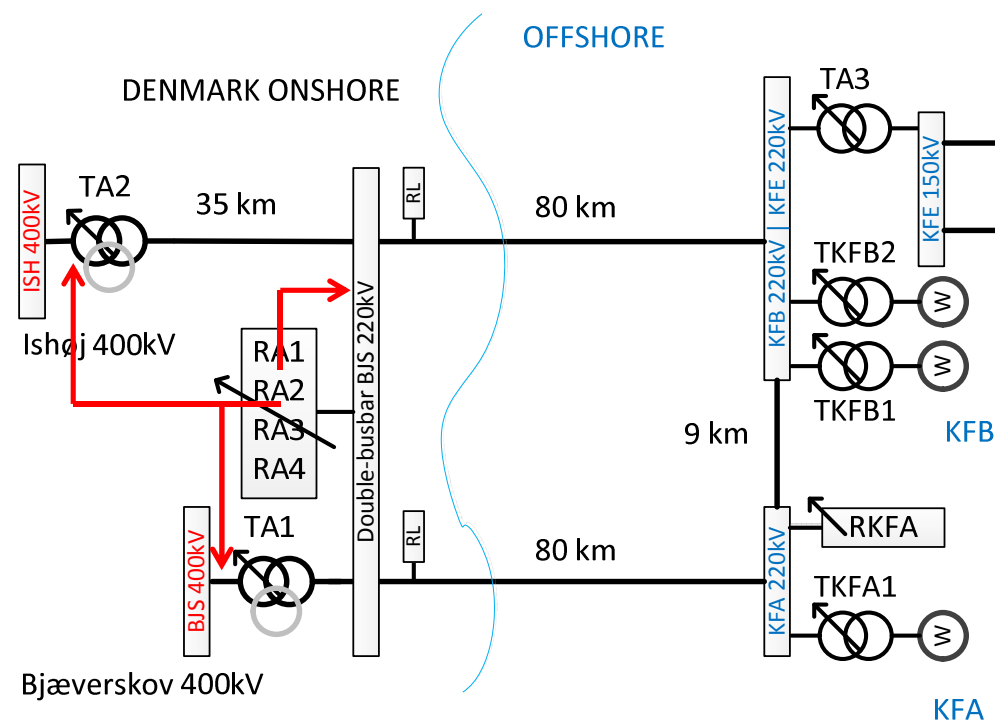
Basic control of n-0 regime

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400/220kV reactive power control:

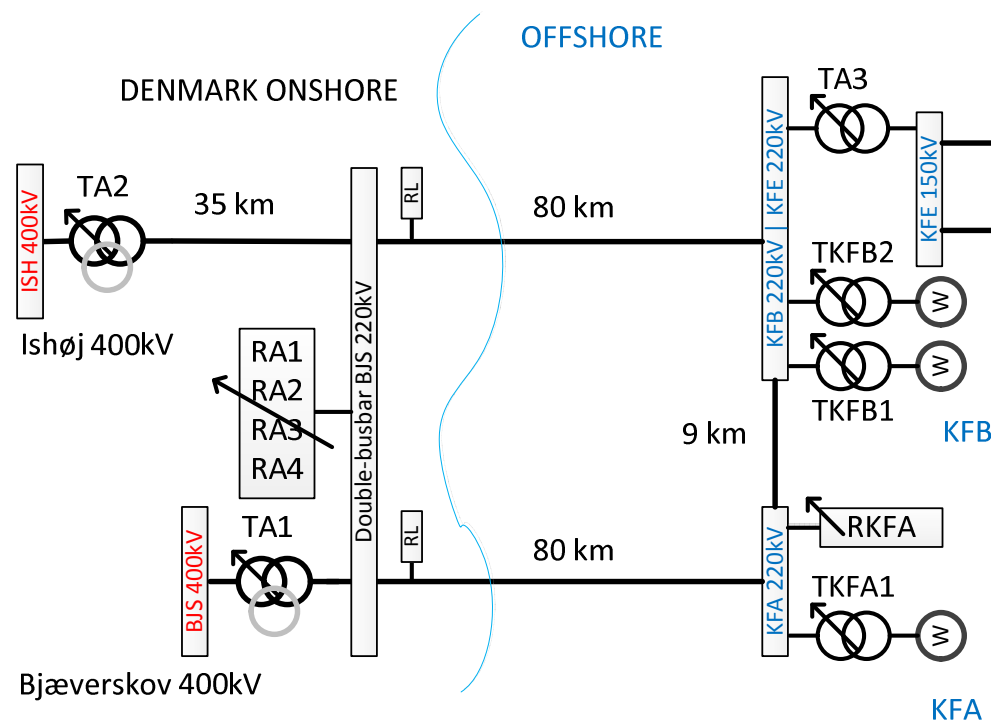
- Target reactive-power exchange of Ishøj and Bjæverskov.
- Tap-position and switch controllers of RA1, RA2, RA3, and RA4.
- Going into voltage control in excessive voltage in BJS 220kV.



Several n-1 regimes

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

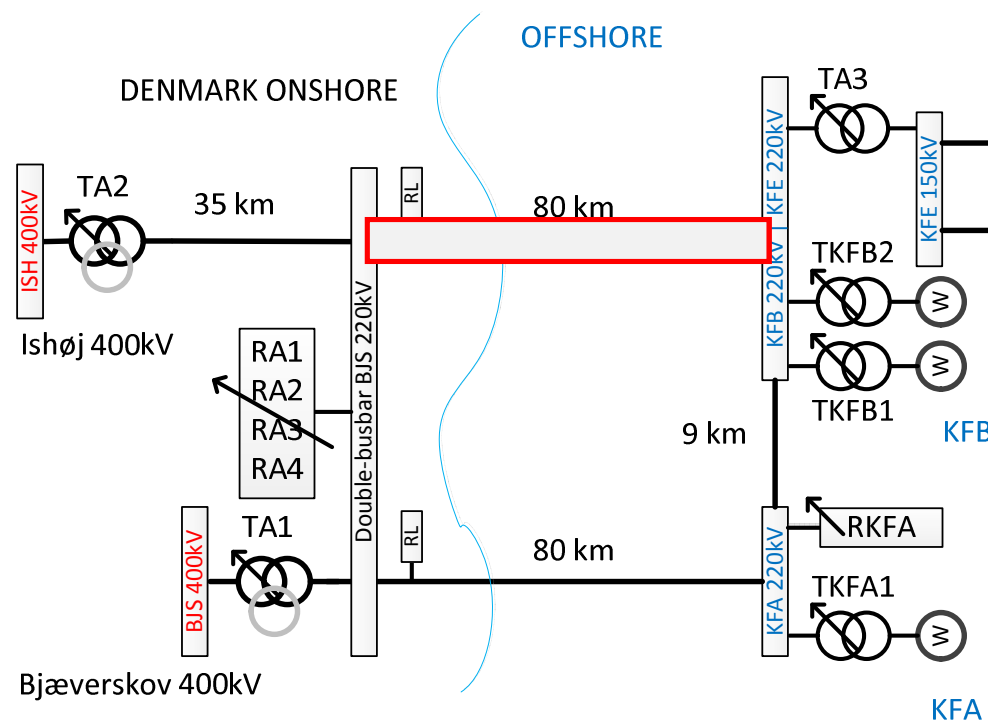
- A 220kV cable outage.
- A 400/220kV transformer outage.
- BJS 220kV separation.
- Full separation.
- Separation from 150kV infrastructure.
- KFB island.
- KFA and KFB island.



Interconnected n-1 regimes

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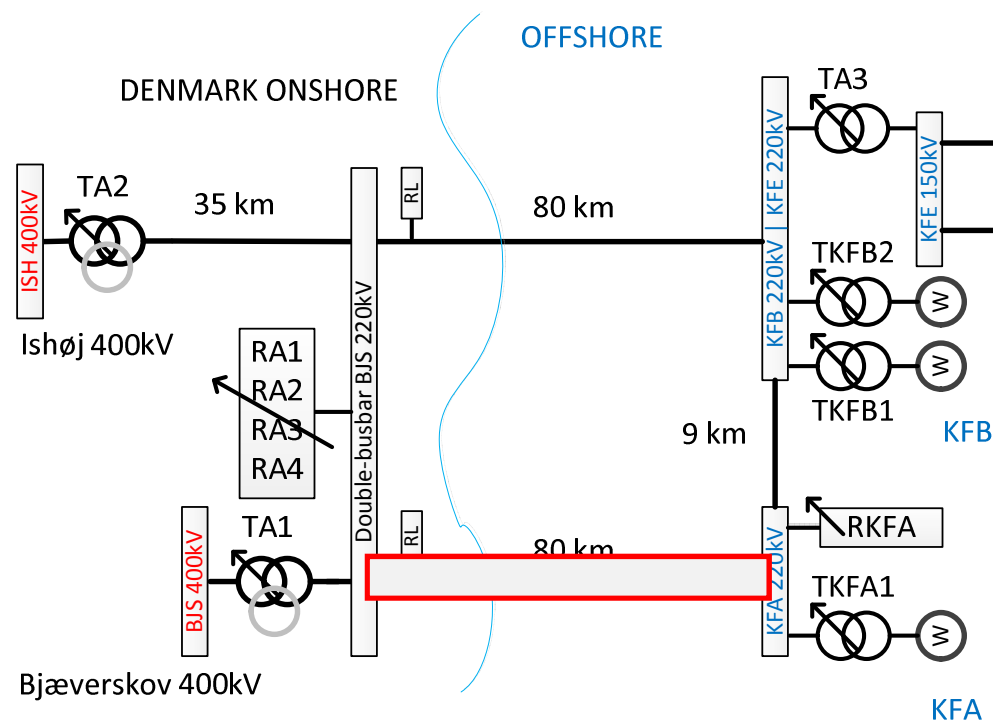
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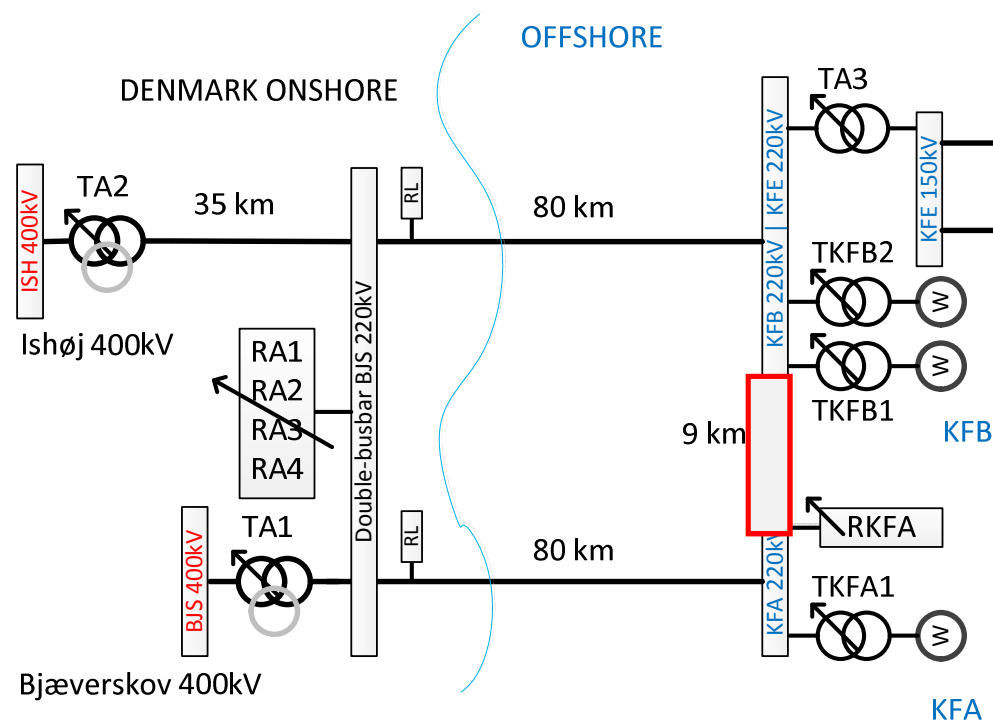
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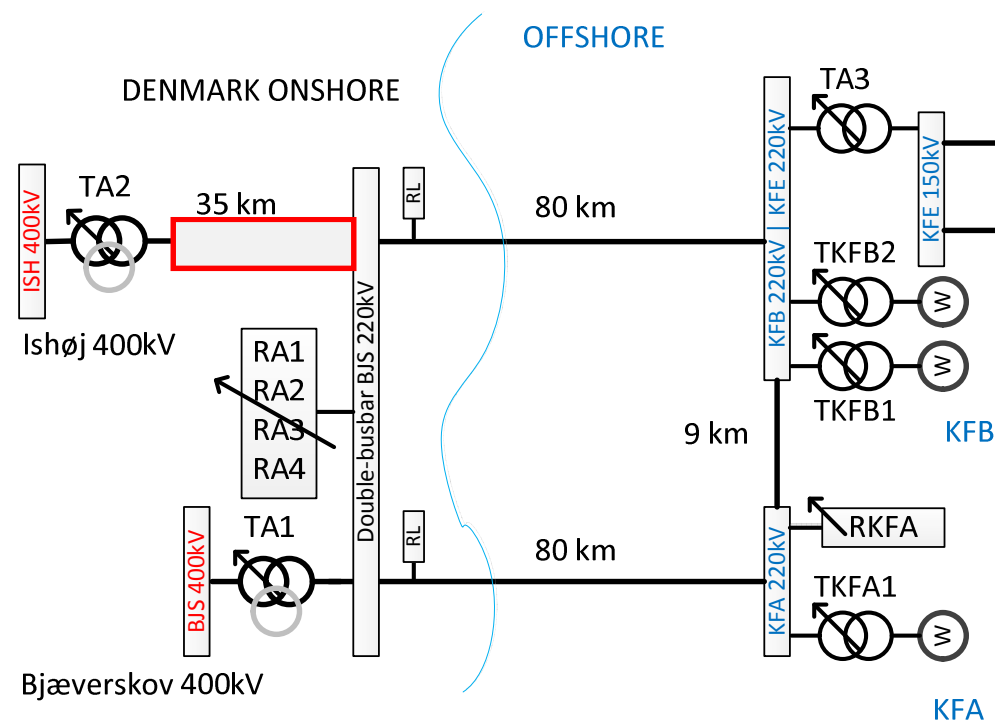
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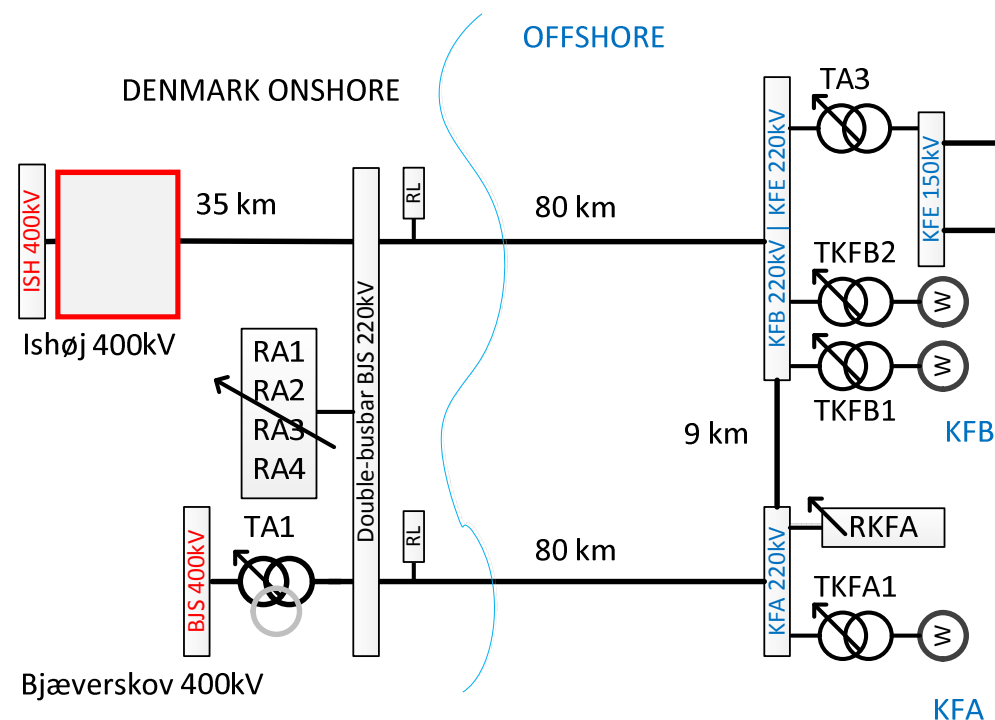
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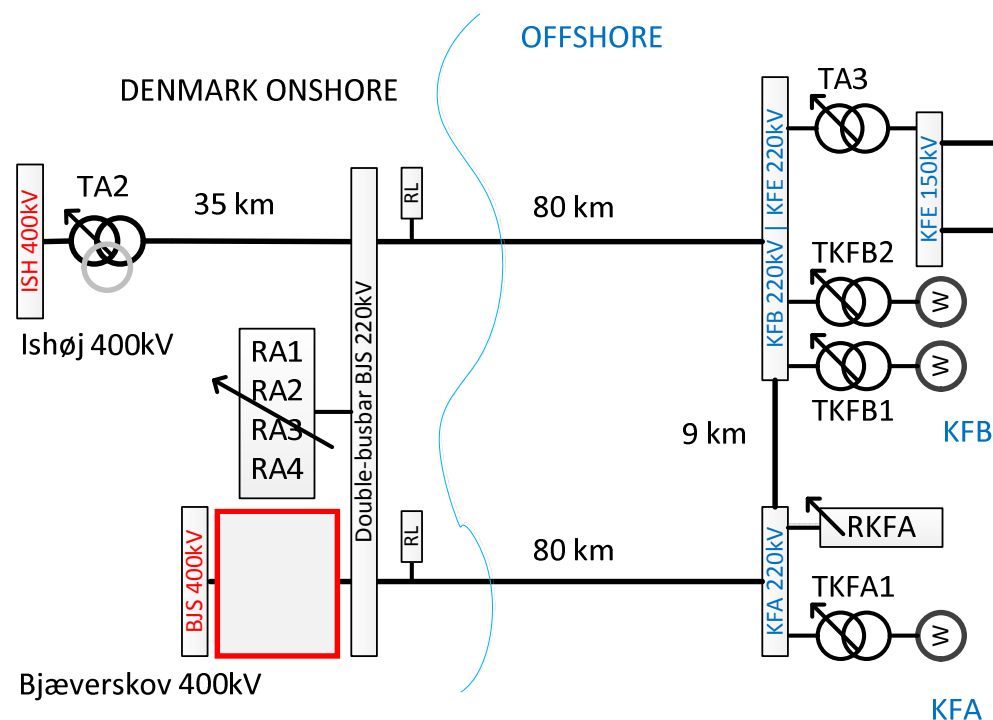
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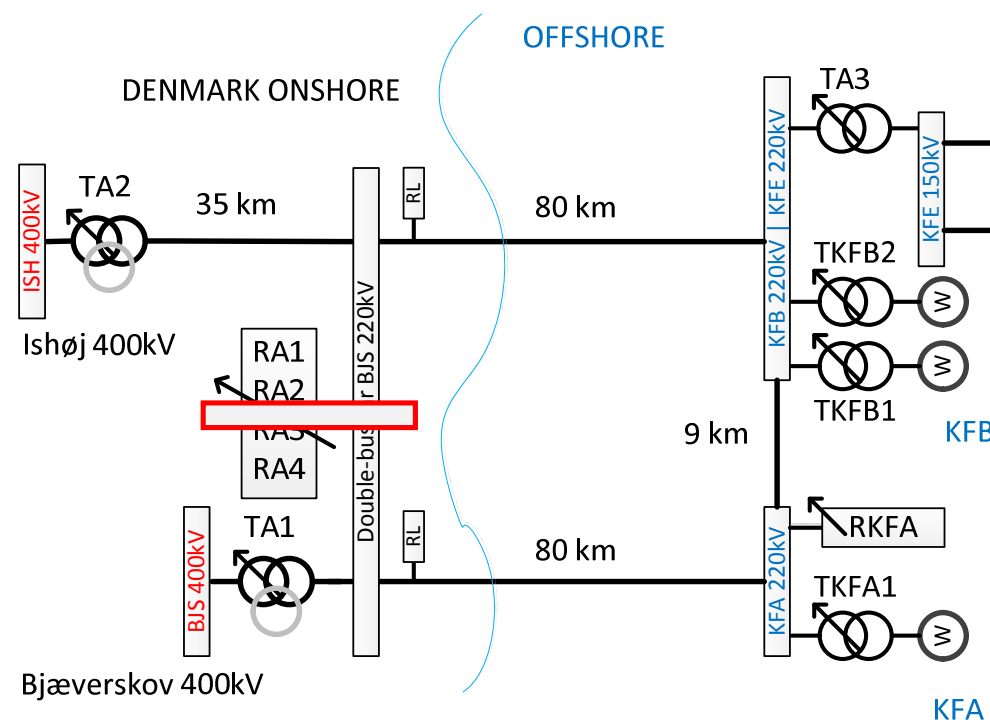
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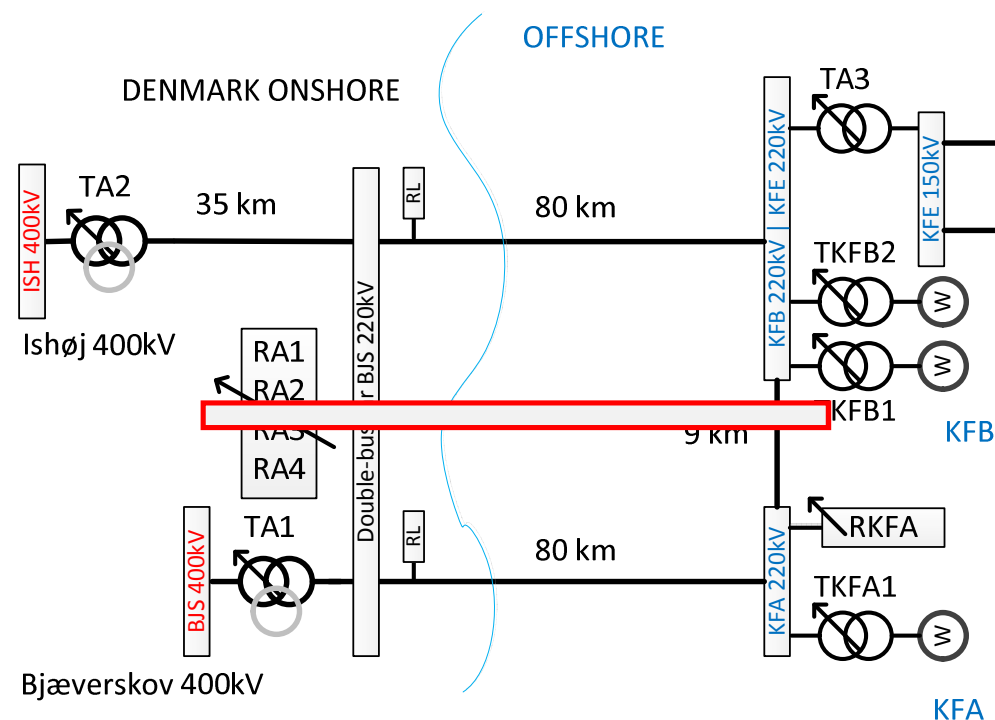
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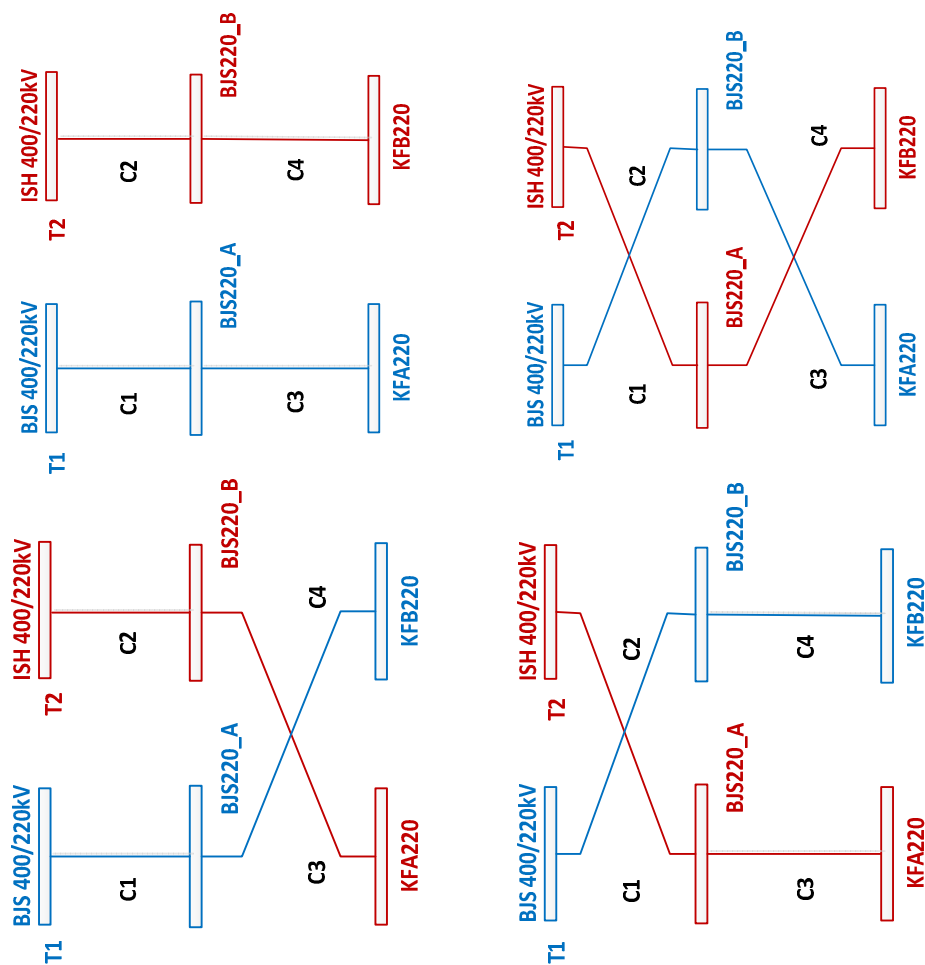
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Full separation: Cross-coupling detection

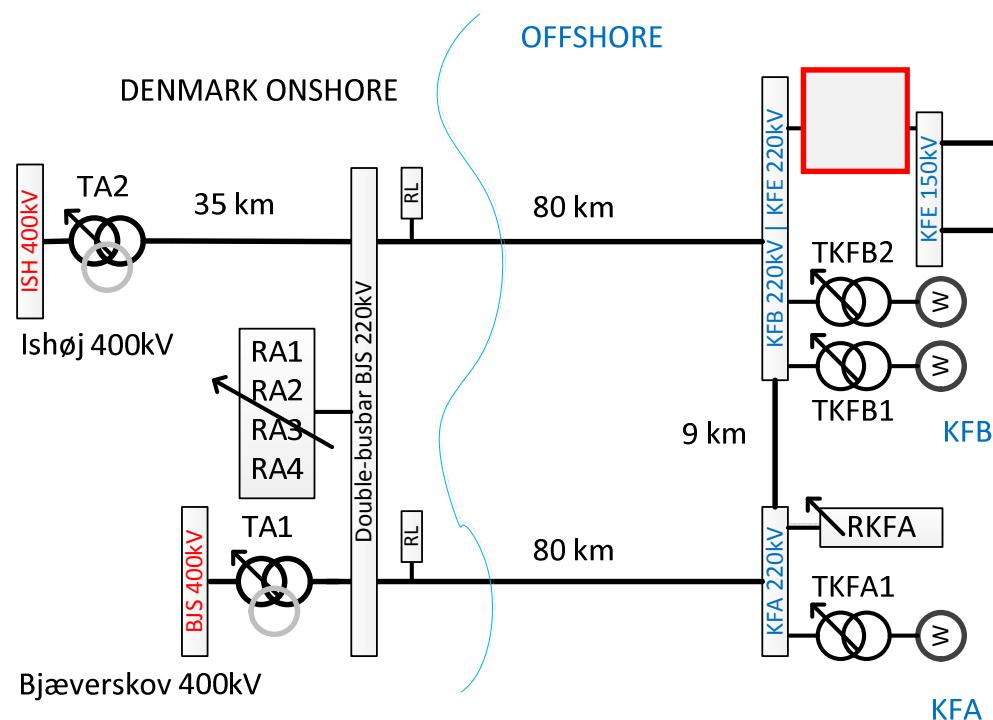


- Connection between onshore transformers and offshore platforms through the double-busbar system.
- Connection between reactors and the 400kV grid-connection points through the double-busbar system.
- Preparedness for separate operation.

Separate n-1 regimes

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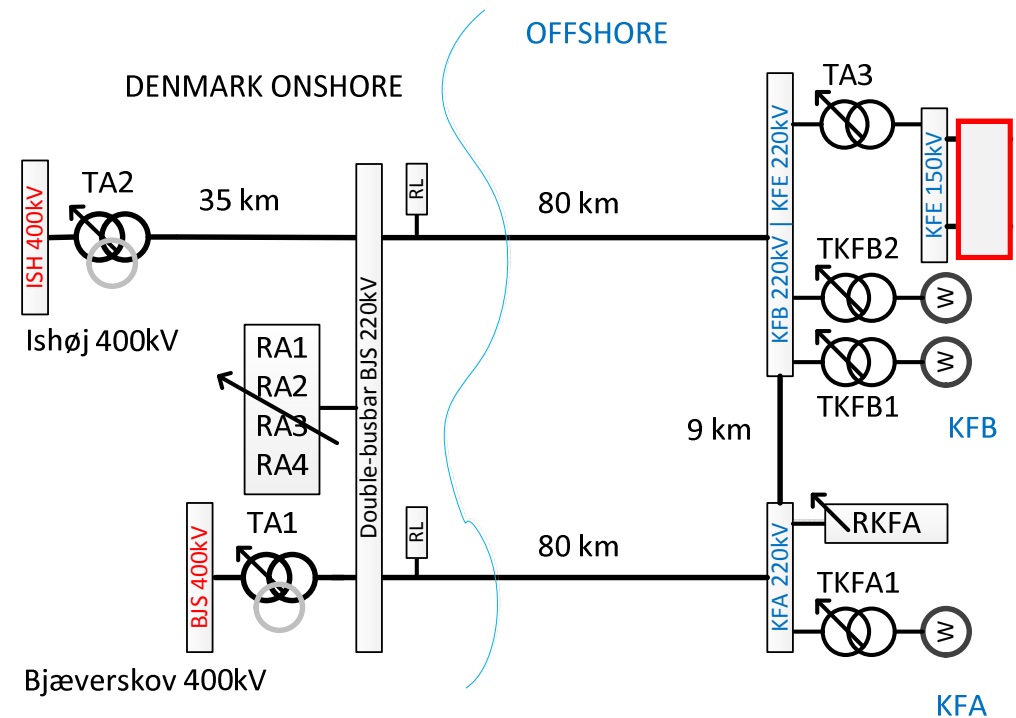
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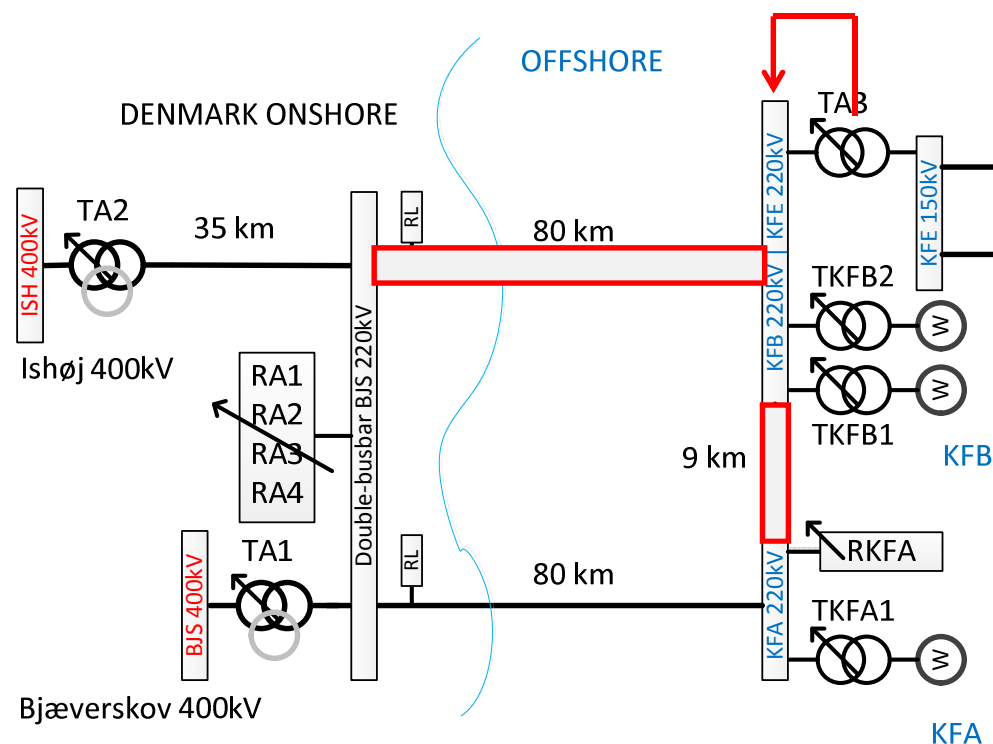
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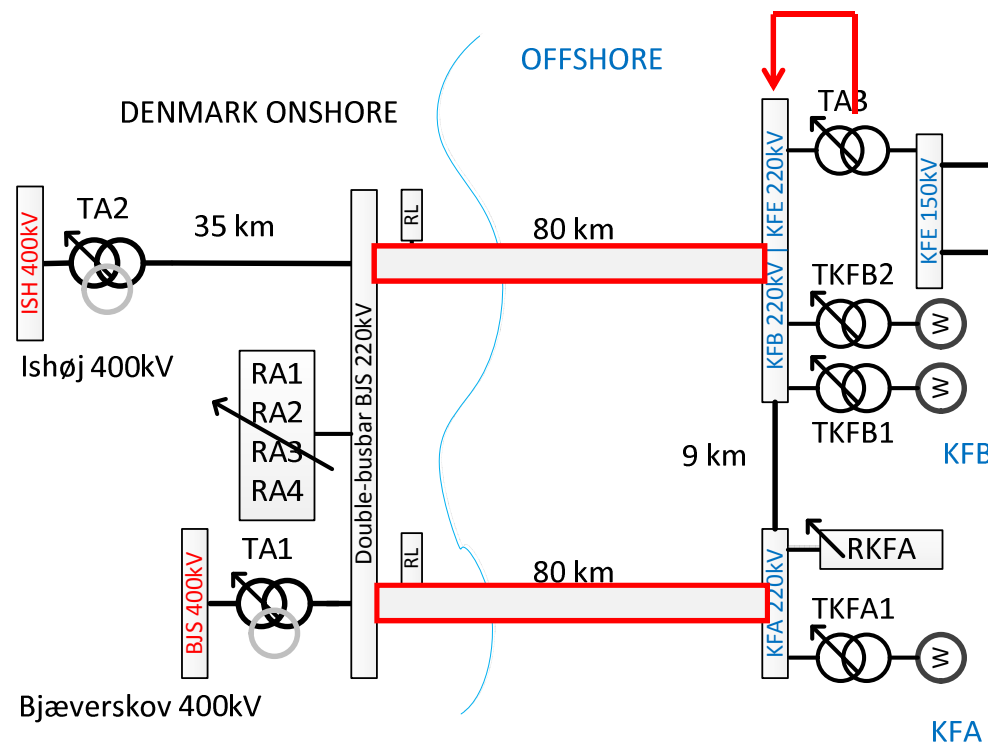
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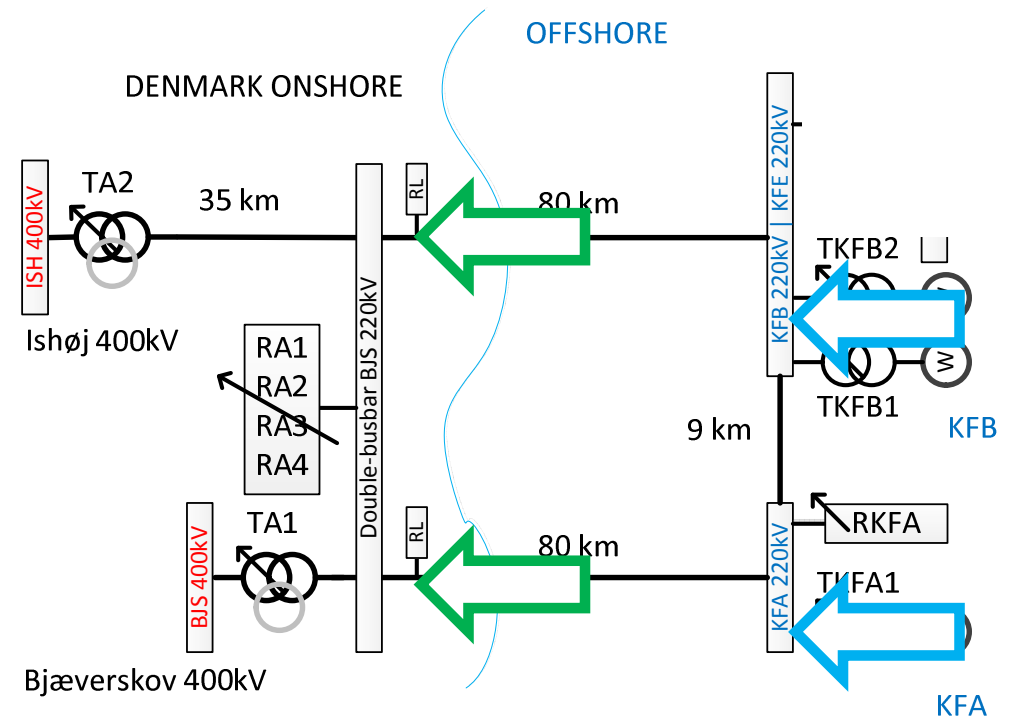
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Power flow patterns

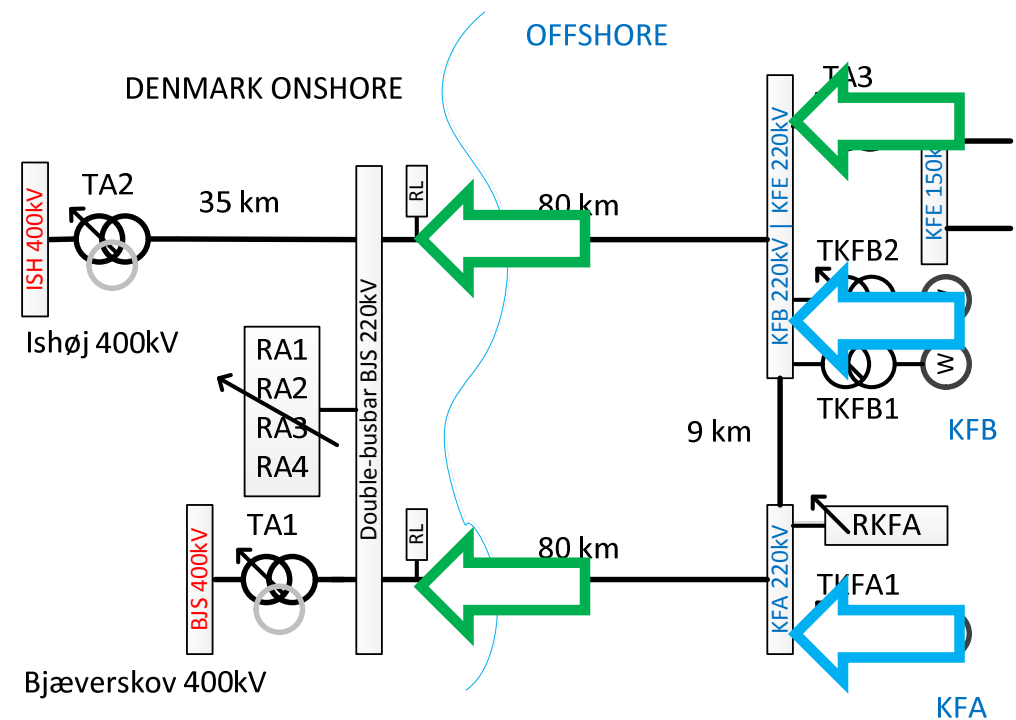
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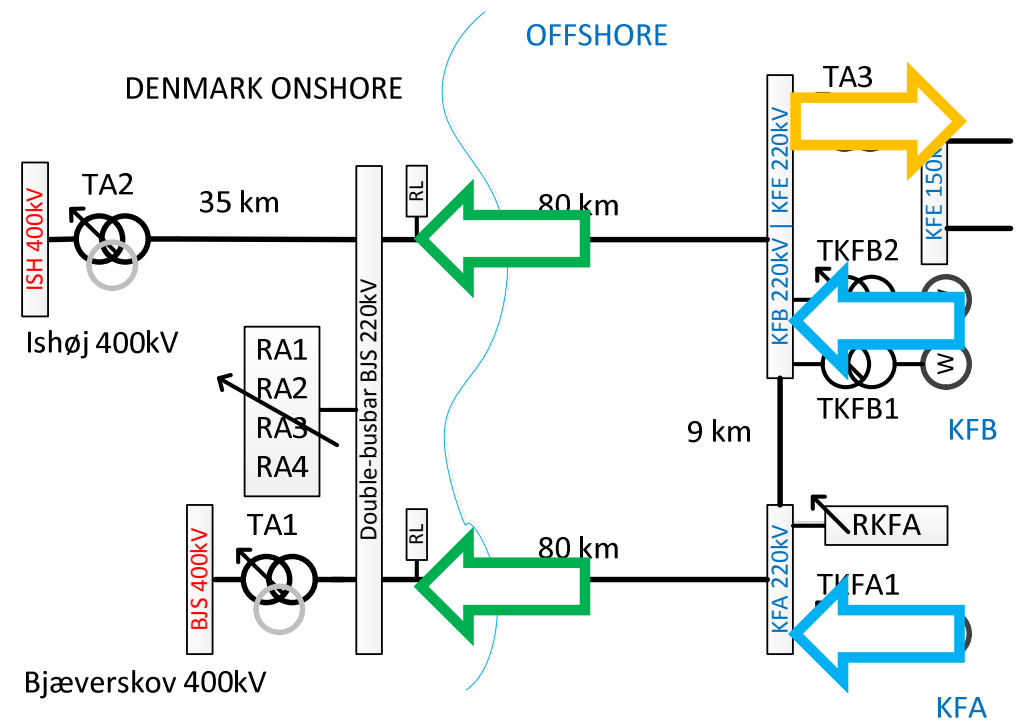
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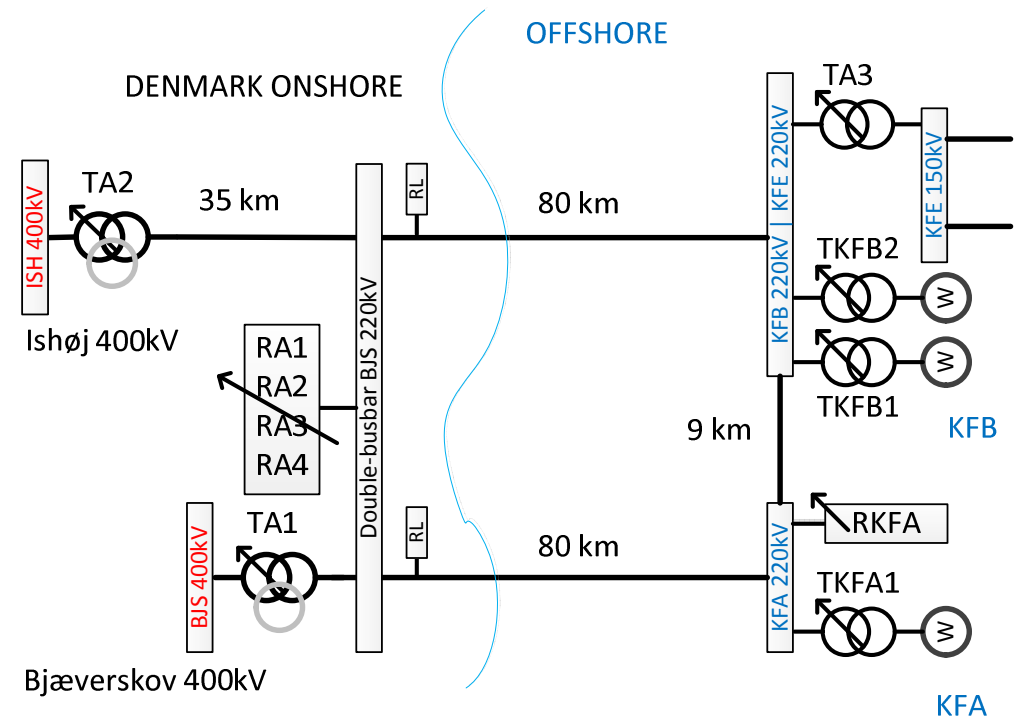
But the Kriegers Flak grid is special. The power transport can go with or without wind and both directions.



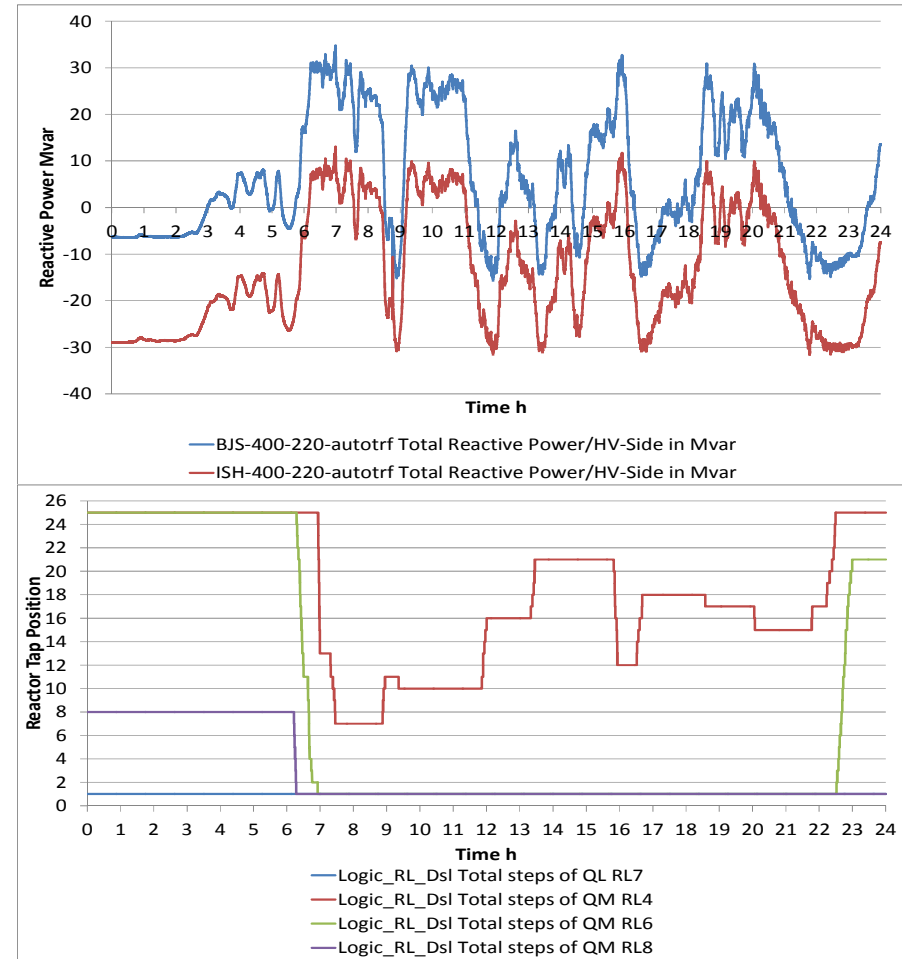
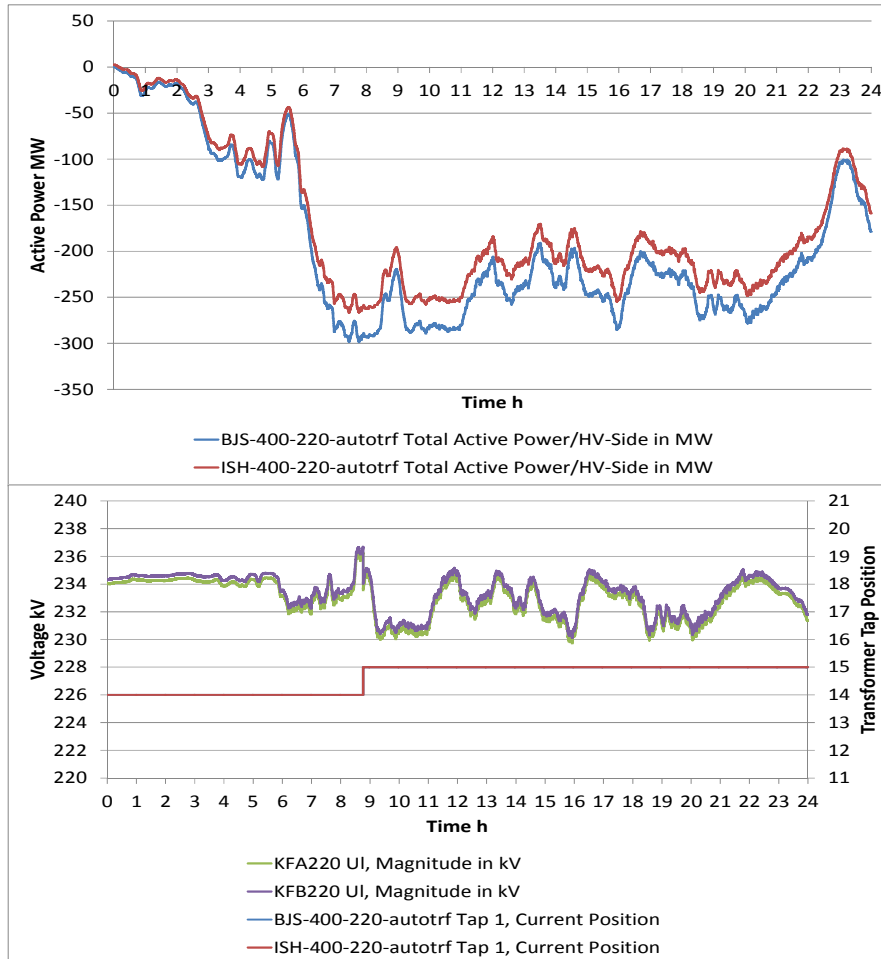
Secure and robust control

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.

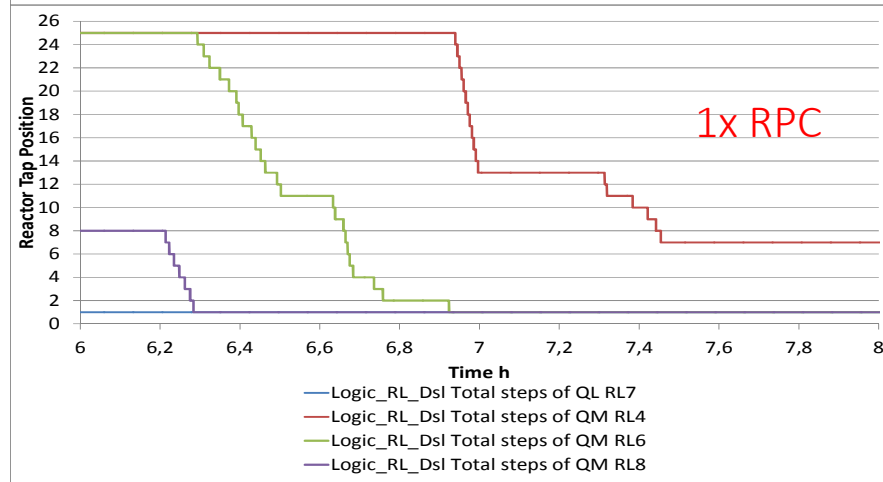
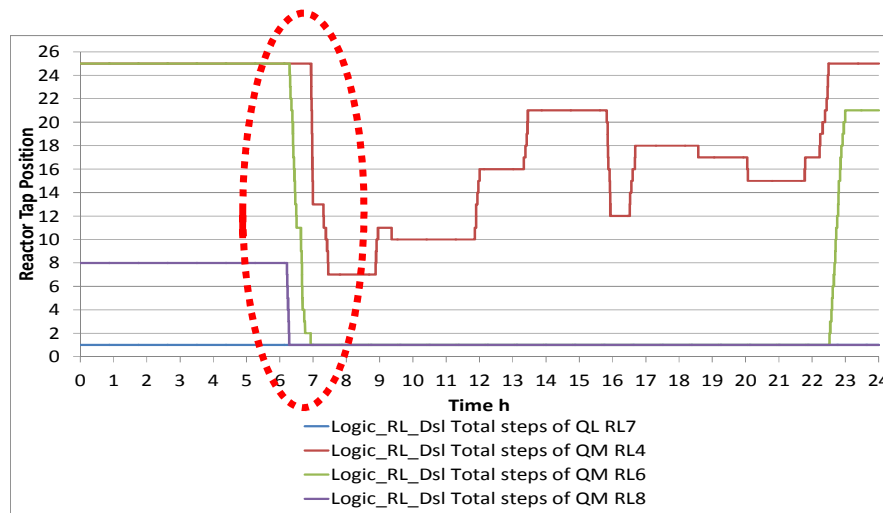
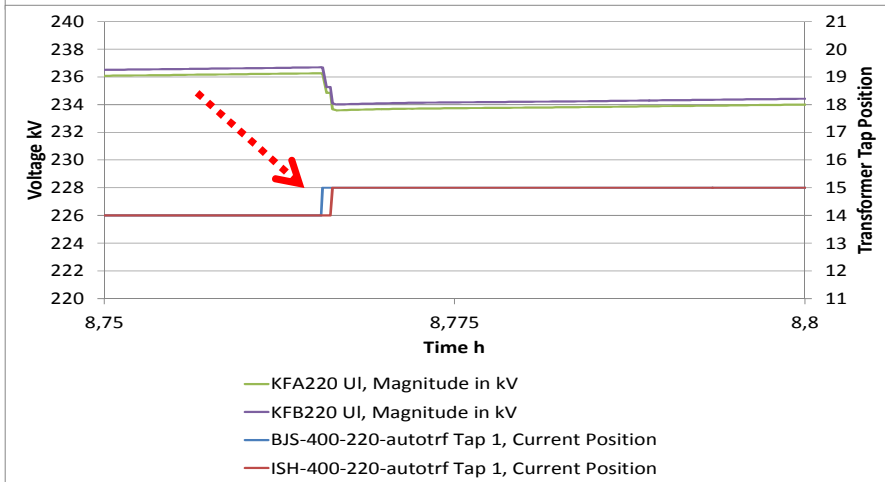
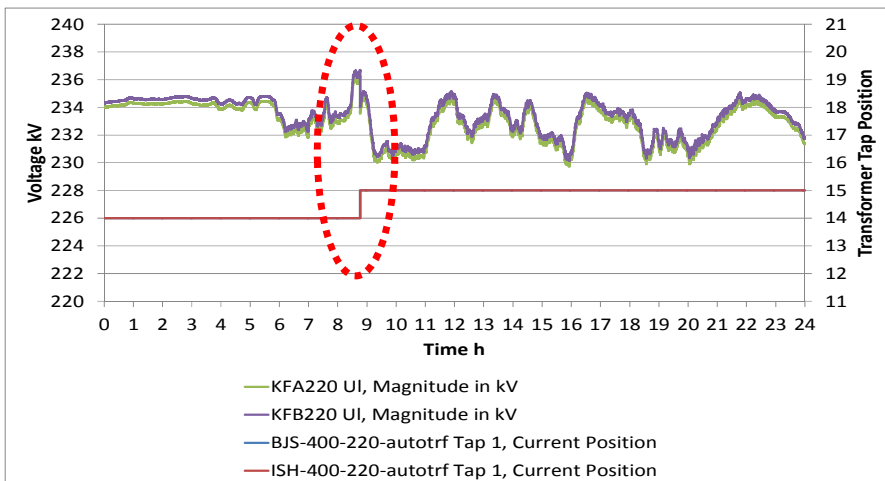


Simulation normal n-0 operation



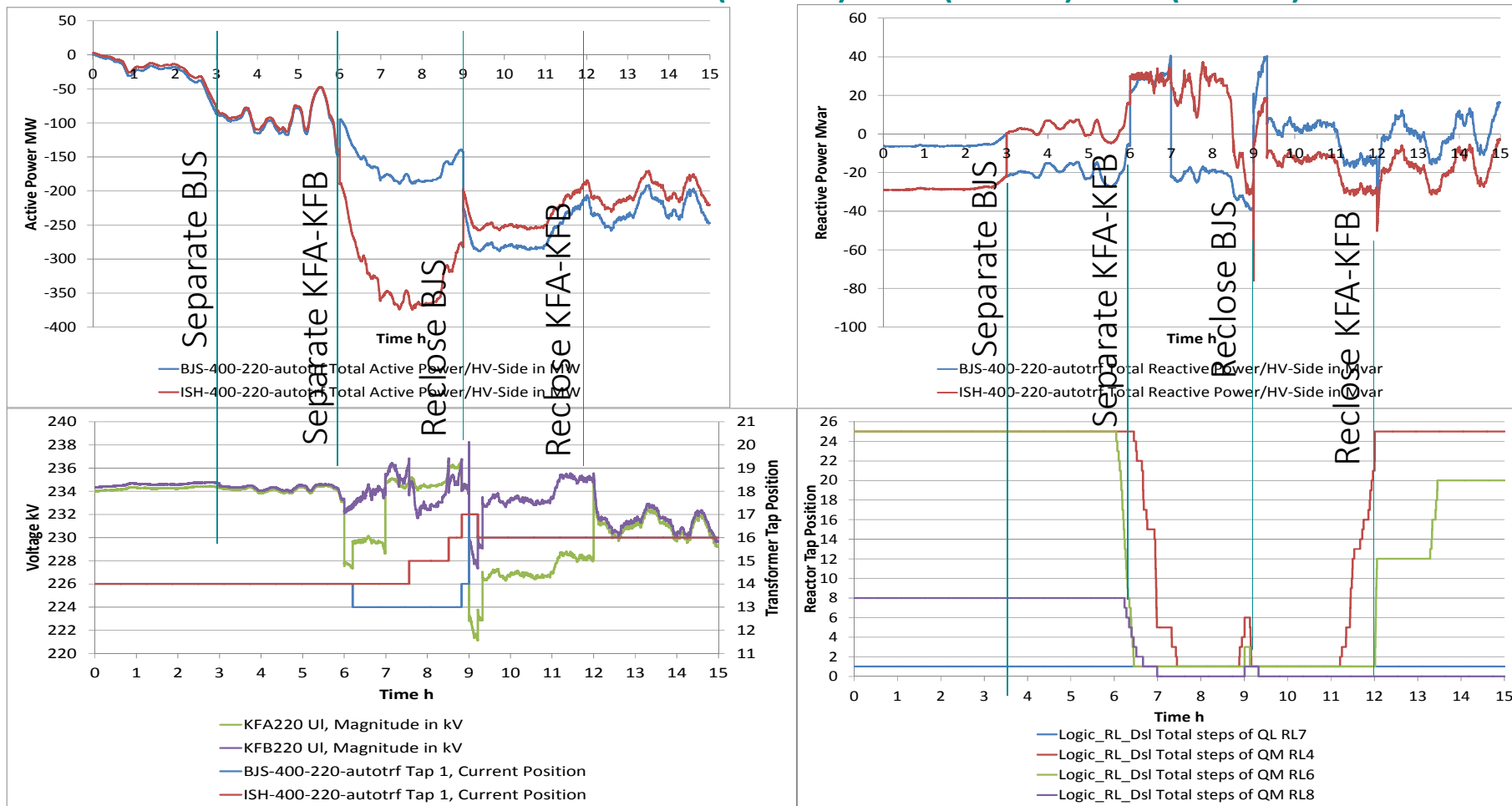
Preconditions: 24 hours, 1 minute resolution, wind power fluctuation

Closer look at n-0



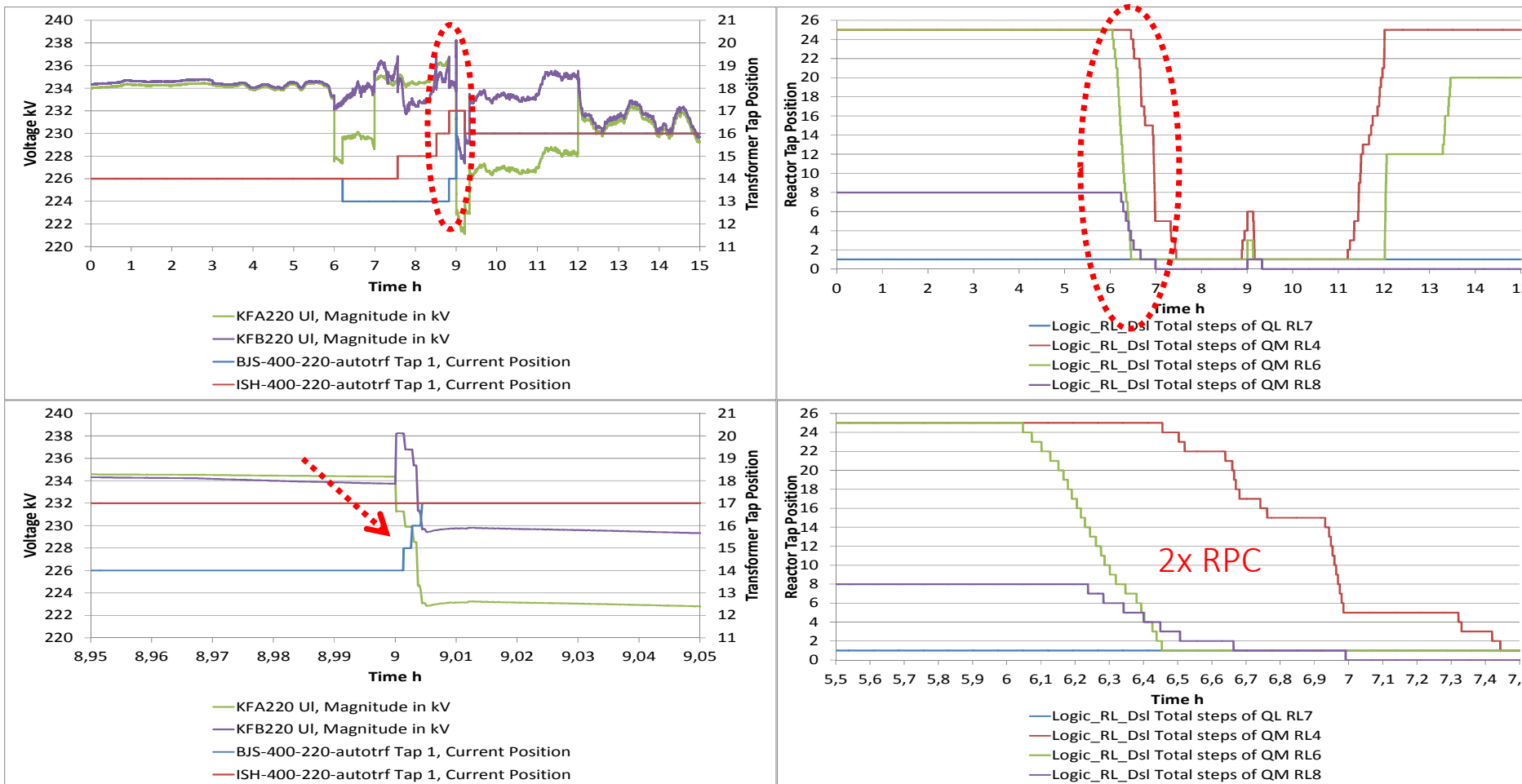
Number of steps over 24 h: TA1/TA2: 1/1. RL: 0/0/0/0. VSR: 48/35/6.

Simulation transitions (n-0) → (n-1) → (n-0)



Preconditions: 15 hours, 1 minute resolution, wind power fluctuation

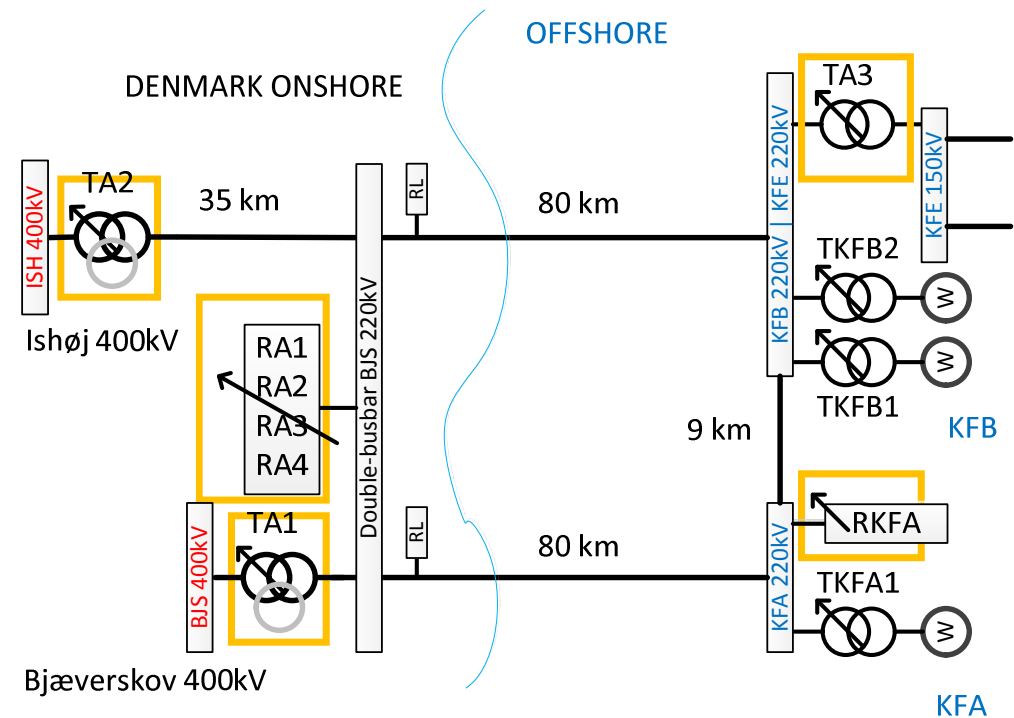
Closer look at transition – reclose BJS220



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>