Kriegers Flak - Combined Grid Solution KF CGS

Experiences from project execution and preparing for operation

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Agenda

1. Intro: Trailer Kriegers Flak – Combined Grid Solution

2. Project Overview: Kriegers Flak – Combined Grid Solution

3. Challenges, opportunities & lessons learned

4. Electrical power transmission and control principles
1. Intro: Trailer Kriegers Flak – Combined Grid Solution
Kriegers Flak - Combined Grid Solution

2. Project Overview: Kriegers Flak – Combined Grid Solution

Elke Kwapis
2. Project Overview Kriegers Flak – Combined Grid Solution KF CGS

A common project of German TSO 50Hertz and Danish TSO Energinet, co-financed by the European Energy Program for Recovery (EU)

The Kriegers Flak - Combined Grid Solution is the world’s first hybrid interconnector/OWP system.

It combines:

• the radial grid connections of the German OWPs Baltic 1 & 2 and the future Danish OWP Kriegers Flak with

• a cross-border interconnector between Denmark and Germany, connecting the German north-eastern region with the Danish area of Sjaelland

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**Diagram:**

- **Denmark:**
  - Energinet National Control Center
  - SS Extension
  - Green – existing and newly built KF AC infrastructure Energinet

- **Germany:**
  - 50Hertz Transmission Control Center
  - OSS KFE
  - Sea Cables
  - Red – KF CGS
  - Blue – existing OWP infrastructure 50Hertz

- **MIO Mastercontroller for Interconnector Operation**

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Co-financed by the European Union
European Energy Programme for Recovery
2.1 KF CGS Offshore Parts – OSS extension module KFE and Sea Cables

- EPCI for two AC sea cables connecting OSS Ba2 with OSS KFE
- EPCI for the HVAC offshore platform „KFE“ as extension of Kriegers Flak OSS KFB

Offshore platform **KFB** (installed in 2018) connects the Kriegers Flak wind park to the Danish onshore grid. The **KFB** platform is combined with the extension module **KFE** on one gravity base foundation.

Main components on **KFE**: transformer (connecting point of the German with the Danish side) and switchgear.

One of the two KF CGS **AC sea cables** (150kV) during installation campaign in front of KFB E platform.

**Baltic 2 Platform**: Existing and already operating. Connecting the Baltic 2 wind park to the German onshore grid.
The Danish and the German transmission grids operate in a slightly different phase, which makes a transformation AC – DC – AC necessary.

In Bentwisch (close to the German coast of the Baltic Sea) a so called back-to-back converter (BtB) is built. It consists of two voltage source converters (VSC).

The converter will change the AC of the Nordic synchronous area into DC and directly back to AC, now adapted to the European synchronous area.
2.3 The MIO (Master Controller for Interconnector Operation)

KF CGS is the first interconnector between two countries (and bidding zones) that integrates infeed from two different national wind farms.

A new kind of calculation and control system is developed to control available capacities and flows of such a complex system.

Tasks of the MIO:

1. Calculating capacity for the market
   (Taking designated topology, equipment ratings and wind forecasts into consideration)
   • In case of wind forecast errors: corrections are needed
   • First priority: Wind

2. Avoid overload of equipment

3. Keep voltage limits for BtB and wind farms
Kriegers Flak - Combined Grid Solution

3. Challenges, opportunities & lessons learned

Elke Kwapis
3.1 Challenges (and Opportunities)

Challenges (and opportunities) related to the specific **pilot characteristics** of the project

Challenges (and opportunities) related to having **two national TSOs** as equal partners in execution and operation

Typical challenges coming from the execution of **complex infrastructure projects**

**CHALLENGES on the way**
3.1 Typical challenges coming from the execution of complex infrastructure projects

Nothing new - no words needed...
3.2 Challenges related to having two national TSOs as equal partners

Need for new ways due to ownership of assets – 50% ownership for each TSO

- Contract setup for main contracts as 3-side contracts with both TSOs as employers
- Regular costs reimbursement for all project execution costs - will proceed in operation phase
- Different insurance approaches of the TSOs had to be aligned.
- System operation and maintenance strategies need to be harmonized.

Mirrored project team – each key function in the project has its counterpart

- High amount of communication traffic
- Energinet in lead for Offshore / 50Hertz in lead for Back-to-Back

Cultural clash – both TSOs are different and so are the people
3.2 Opportunities related to having two national TSOs as equal partners

Best chance on experience exchange between two TSOs at a life project
the goal is the same –

the way to reach it can be very different

- Project setups with companies
- Approaches for contracting
- Grid operation principles
- Best practices and new developments
- Setup for optimal cooperation agreement
- Testing of new team work methods

ROC Drill concept for Commissioning Workshop – result: smart ideas and good team spirit
3.3 Challenges & opportunities related to specific pilot characteristic

Main challenge: OWP infeed vs trading capacity

- There are different legal and market mechanisms on national and EU level for OWP infeed and for interconnectors
- or even no regulations covering the special case of a hybrid system like KF CGS

- Hybrid systems like the KF CGS are usually not covered by existing and future market mechanisms for interconnectors and the legal national frameworks for offshore wind.

- Therefore, a pilot project like KF CGS has to face certain undefined situations and questions. For example:

  What shall be the definition (calculation) for the capacity available to the market when you have fluctuating wind infeed?

- Intense communication is needed with national regulators and on EU level to adapt existing and future regulations to the needs of hybrid systems.
3.3 Challenges & opportunities related to specific pilot characteristic

Challenge: the interconnector infrastructure needs to be integrated into existing and new OWP infeed infrastructure and onshore substations

- Sea cables had to be pulled in and terminated on an operating Baltic2 platform and with very narrow space
- Commissioning and the trial run for the overall KF CGS are planned to have as little impact as possible on the windfarms
- Discussions about compensations for wind farms are necessary
- Proper planning necessary to avoid impacts on existing assets at onshore stations
3.4 Lessons learned

The two main focus areas are:

I. External Stakeholders

Can be: national regulators, politicians, EU, public, approval authorities, wind farm owners, neighbour TSOs, market players, ...

→ Careful stakeholder analysis and monitoring throughout the overall project – keeping in mind the unique character of the project. The more stakeholders are involved, the bigger the effort to manage (secure the right and sufficient resources!)

II. Internal Stakeholders

Can be: project sponsor, both project teams, any other related TSO department,…

Never underestimate the human factor!

More interfaces and more unexpected challenges lead to higher need for communication between the TSOs – to get the right support at the time needed
Kriegers Flak - Combined Grid Solution

4. Electrical Power Transmission and Control Principles

Vladislav Akhmatov
1. Outline of the Kriegers Flak CGS.

2. Already existing infrastructure for connecting of the offshore wind power plants (600 MW Danish and 336 MW German).

3. Added infrastructure for establishment of the interconnector.

4. HVDC VSC Back-to-Back (BtB) in Bentwisch (Germany) because of connecting two large asynchronous areas (400 MW).

5. The offshore infrastructure is HVAC cables and platforms with locations of wind power plants.
Kriegers Flak CGS – Electrical System Assets

- KFA: 200MW
- KFB: 400MW
- KFE: 288MW

Possible extension towards Sweden

Baltic 2: 288MW

Baltic 1: 48MW

HVDC
Kriegers Flak CGS – Electrical System Assets

Denmark

Ishøj 400 kV

Bjæverskov 400 kV

Busbar A
Busbar B

PST

80 km

34 km

80 km

9 km

KFA

KFB

KFE

Possible extension towards Sweden

Baltic 1: 48 MW

Baltic 2: 288 MW

RA1

RA2

RA3

RKFA

Baltic 1: 48 MW

Baltic 2: 288 MW

HVDC

380 kV/150 kV/30 kV
400 MVA

Germany
Kriegers Flak CGS – Electrical System Assets

220kV meshed offshore system
Kriegers Flak Combined Grid Solution (CF CGS)

Kriegers Flak CGS – Electrical System Assets

- **KFA**: 200 MW
- **KFB**: 400 MW
- **Baltic 1**: 48 MW
- **Baltic 2**: 288 MW

220kV meshed offshore system

150kV cable system

Possible extension towards Sweden

Baltic InteGrid Final Conference, Berlin, Germany
Kriegers Flak CGS – Electrical System Assets

220kV meshed offshore system 150kV cable system HVDC BtB

Ishøj 400 kV
Bjæverskov 400 kV

Busbar A
Busbar B

PST
80 km
34 km
9 km
80 km

KFA: 200MW
KFB: 400MW
KFEBAZ
BAE
BwW

220/150kV
450MVA
380kV/150kV/30kV
400MVA

BAZ
BAE
BwW

Possible extension towards Sweden

KFA
KFB
KFE
BAZ
BAE
BwW

HVDC
BwC

25 km
60 km
75 km

RA1
RA2
RA3
RKFA

25-27/02/2019
Baltic InteGrid Final Conference, Berlin, Germany
How to operate Kriegers Flak CGS?

- **KFA**: 200MW
- **KFB**: 400MW
- **KFE**: Baltic 2: 288MW
- **BwC**: Baltic 1: 48MW
- **Possible extension towards Sweden**
- **Busbar A**
- **Busbar B**
- **Ishøj 400 kV**
- **Bjæverskov 400 kV**
- **220/150kV 450MVA**
- **380kV/150kV/30kV 400MVA**
- **HVDC**
- **RA1**
- **RA2**
- **RA3**
- **RA4**
- **PST**
- **BJS220**
- **TA1**
- **TA2**
- **RKFA CB01**
- **9 km**
- **80 km**
- **25 km**
- **60 km**
- **75 km**
- **34 km**

Baltic InteGrid Final Conference, Berlin, Germany
How to operate Kriegers Flak CGS
Matter of control
How to operate Kriegers Flak CGS
Matter of control
How to operate Kriegers Flak CGS
Matter of control

Ishøj 400 kV

Bjæverskov 400 kV

BJS220

80 km

34 km

9 km

80 km

80 km

25 km

60 km

75 km

Possible extension towards Sweden

WPPC

Baltic 1: 48 MW

TA1

RA1

RA2

RA3

Baltic 2: 288 MW

WPPC

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How to operate Kriegers Flak CGS

Matter of control

AVR/RPC

DLR

WPPC

Possible extension towards Sweden

Baltic 2: 288MW

Baltic 1: 48MW

Busbar A

Busbar B
How to operate Kriegers Flak CGS
Matter of control \textit{coordination}

Interface to Master Controller for Interconnector Operation (MIO)
Layer 1: Dots and lines – Main idea

What and where to build?
Layer 1: Dots and lines – Main idea

Layer 2: Assets

What equipment?
Layer 1: Dots and lines – Main idea

Layer 2: Assets

Layer 3: Control of Assets

How equipment works?
Layer 4: Control Coordination

How interconnector works?

Layer 3: Control of Assets

Layer 2: Assets

Layer 1: Dots and lines – Main idea
Kriegers Flak Combined Grid Solution – Four Technical Layers

Each layer is needed for success:

Layer 1: Dots and lines – Main idea

Layer 2: Assets

Layer 3: Control of Assets

Layer 4: Control Coordination
Energy transport

1. Business As Usual.

2. Offshore wind to Land
   (High wind scenarios)
1. Interconnector.

2. Offshore wind to Land

(High wind scenarios)
1. Interconnector.

2. Offshore wind to Land

(High wind scenarios)
1. Land to Offshore.

2. Then Offshore to Land

(Low/No wind scenarios)
1. Land to Offshore.

2. Then Offshore to Land

(Low/No wind scenarios)
Lessons learned from this presentation

1. Kriegers Flak CGS utilizes existing and added offshore and onshore assets.

2. Grid-connection of Offshore Wind and an Interconnector between Denmark and Germany.

3. Meshed offshore HVAC grid combined with HVDC Back-to-Back in Germany (Bentwisch).

4. Technical - “The Four Layers” combining the idea, assets and advanced control.

5. Energy transports – Business as usual from Platforms to Land.

6. Energy transport – From Land into Platforms and then to Land.
Acknowledgements

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However, for the avoidance of doubt, the European Commission is not responsible for any use that may be made of the information contained in this paper.
1. KFE platform is the point-of-settlement.

2. Wind power forecasts, availability of equipment, Dynamic Line Rating (DLR), onshore grid limitations.

3. Optimal Power Flow (by the MIO).

4. Capacity calculations by 5 min. to the market.

5. Market schedule received by the MIO.

6. The MIO secures the market schedule (adjusting BtB):
   - Available transfer capacity utilized by wind power and market to a maximum of 100%.
   - Higher grid access priority of wind power than for market schedule (in case of congestions: market will be curtailed first).
   - The wind power from Baltic 1 and Baltic 2 must be transmitted to Germany and the wind power from KFA and KFB to Denmark, respectively.

7. In case of forecast errors or equipment overloading:
   - Curtail the market schedule, if necessary to 0 MW.
   - If not resolved, curtail the wind power of the relevant section.
   - Curtail less possible.
1. Kriegers Flak CGS utilizes existing and added offshore and onshore assets.
2. Grid-connection of offshore wind power and an interconnector between Denmark and Germany.
3. Most possible assets are onshore.
4. HVDC Back-to-Back in Bentwisch (Germany).
5. Meshed offshore HVAC grid.
6. Energy and power transport from offshore platforms to the onshore grids (usual way), and in the opposite direction.
9. Automatic voltage and reactive power control (AVR/RPC).
10. Advanced control of wind power plants, BtB, other equipment.
11. Master Controller for Interconnector Operation – the must for coordination.
12. Several other control systems apply (not included in this presentation).