OPENMODELICA WORKSHOP, 02.02.2026

Operational experience with real-time optimization of a hybrid offshore grid and new directions with neural ODEs

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Agenda

Real-time optimization of KriegersFlak hybrid offshore grid

Examples of actual operation

New challenges with sector coupling with hydrogen

New model building pipeline for neural enhanced ODEs

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Kriegers Flak Combined Grid Solution

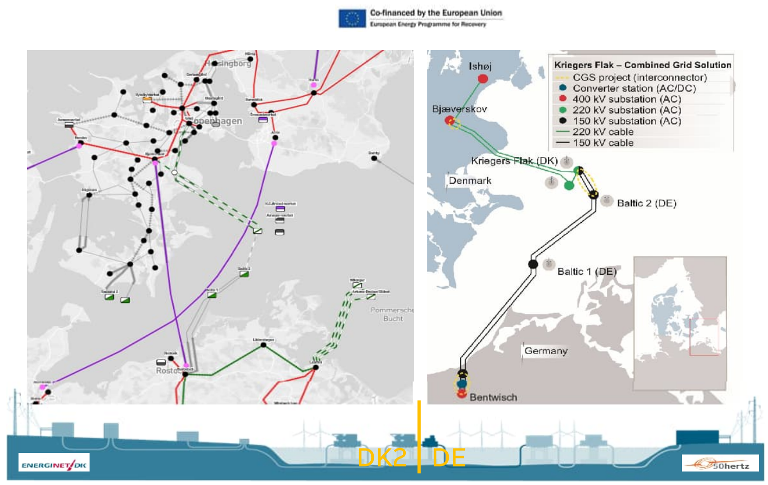
Overview

KFCGS interconnector

New 400 MW interconnector utilizing existing and newly built offshore wind power collector grids of the two TSO's 50Hertz Transmission and Energinet.dk

For wind farms with installed power of 950 MW

Require Master-controller for Interconnector Operation (MIO)



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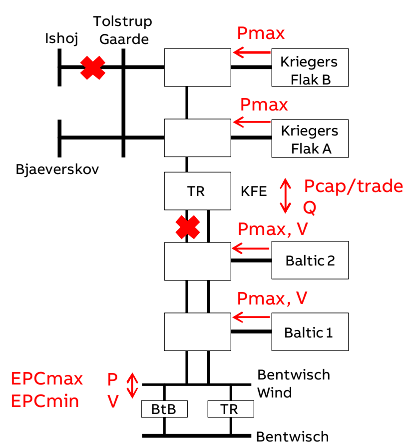
Kriegers Flak Combined Grid Solution

Operation concept

Major functions

1. Forecast available transfer(market) capacity at KFE (POR)
2. Set BtB power order according to agreed market flow and wind power
3. Adjust BtB power order if POR deviates due to forecast errors of wind
4. Adjust BtB and/or limit wind farms if any components are overloaded due to:
   - Forecast errors or;
   - Contingencies
5. Adjust BtB V reference at BwW in order to keep Q exchange at KFE and provide V set point recommendations for wind farms
6. Generate EPC limits for BtB



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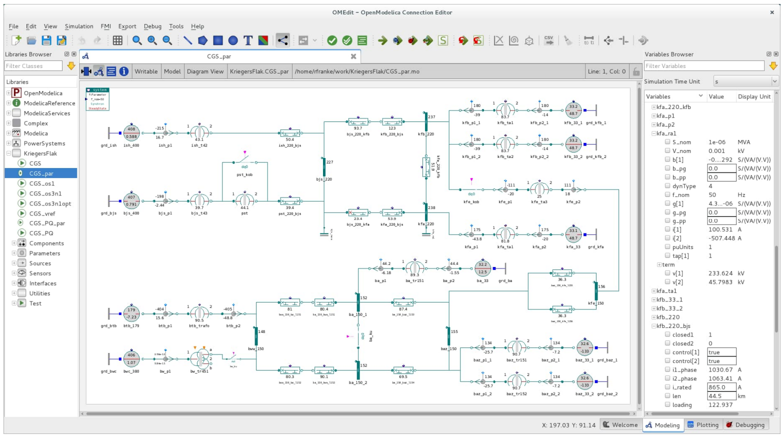
Modelica system model

Basing on PowerSystems library using dq phase system (RMS)



OpenModelica features

- Use of pre-built Modelica libraries
- Graphical composition of application model
- Model translation to fast executable C++ code

Model characteristics

- Equations/Variables: 4722
- Non-triviial equations: 788
- Size of core equation system: 81
- Model inputs u, z: 144
- Model outputs y: 335

Model-based predictive optimization

- Optimize power flows over K time steps, e.g. 96 steps for 15min intervals of one day
- Real-time need: solve time steps in parallel

ABB

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ABB Dynamic Optimization

Treat optimal control programs basing on simulation models

For dynamic system model and sample time points tk , t0 < t1 < … < tK
find control u (and/or initial states x(0)) that minimize criterion J
subject to mixed discrete/continuous model, initial conditions
and further constraints g

$$J = \sum_{k=0}^{K} f_0\left[k, \begin{pmatrix} x_d(k) \\ x_c(t_k) \end{pmatrix}, \begin{pmatrix} u_d(k) \\ u_c(t_k) \end{pmatrix}\right] \rightarrow \min_{x_d(0)\ u_d(0) \atop x_c(t_0)'\, u_c(t_0)}$$

FMU ME

$$x_d(k+1) = f_d[k, x_d(k), x_c(t_k), u_d(k)], \quad x_d(0) = x_{d0}, \quad k = 0,1,\dots,K$$

$$\frac{dx_c(t)}{dt} = f_c[t, x_d(k(t)), x_c(t), u_c(t)], \quad x_c(t_0) = x_{c0}, \quad t \in [t_0, t_K]$$

$$y(k) = h[k, x_d(k), x_c(t_k), u_d(k)], \quad k = 0,1,\dots,K$$

$$g[y(k(t)), u_d(k(t)), u_c(t)] \geq 0$$

ABB

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Why OpenModelica C++ runtime

- Deterministic code for real-time control applications (explicit destructor calls instead of garbage collector)
- Discrete-time models with clocked states (cf. FMI 3, so far as proprietary extension of C++ FMI 2)
- Support parallel optimization with multiple FMU instances in one process
- Powerful vectorization / array features
- Faster execution speed, in particular if compiled with code optimization

- Drawback: longer compilation time; gradually improving with each new version of C++ compiler

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Real-time optimization of KriegersFlak hybrid offshow grid

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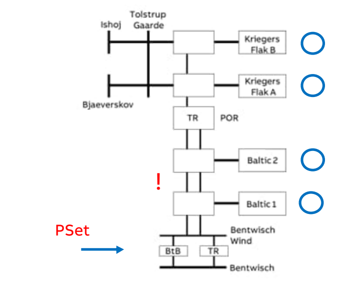
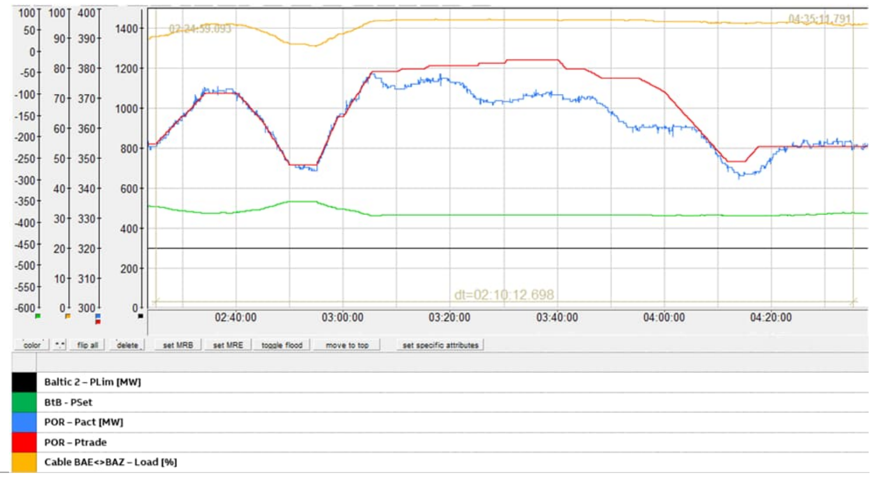
Real-time optimization

Controlling planned power transfer, subject to network constraints and disturbances

- Higher wind power than expected
- Cable BAE – BAZ is fully loaded
- → reduce power transfer through POR (blue vs red) to maintain cable limit





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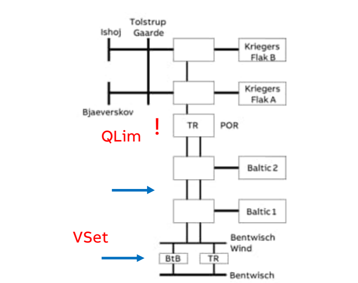
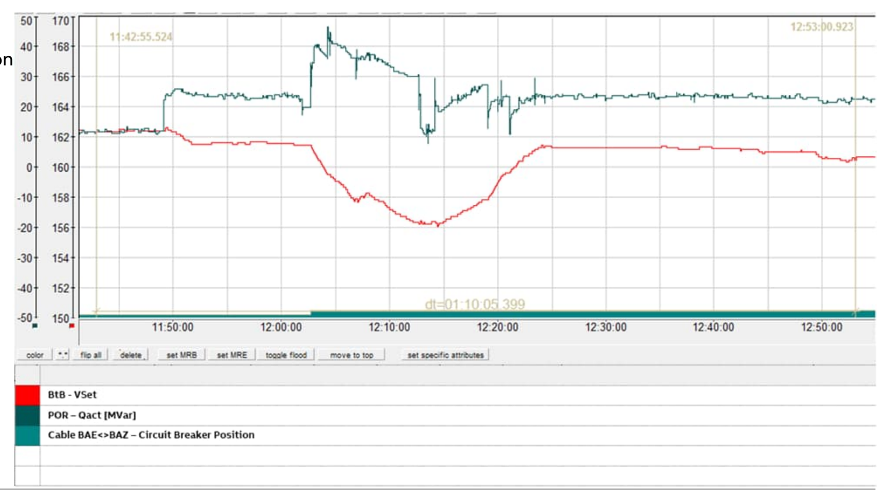
Real-time optimization

BtB voltage control, subject to POR reactive power constraints

- Cable BAE – BAZ goes into operation
- Reactive power flow through POR increases
- → reduce BtB voltage set point to stay in allowed limit





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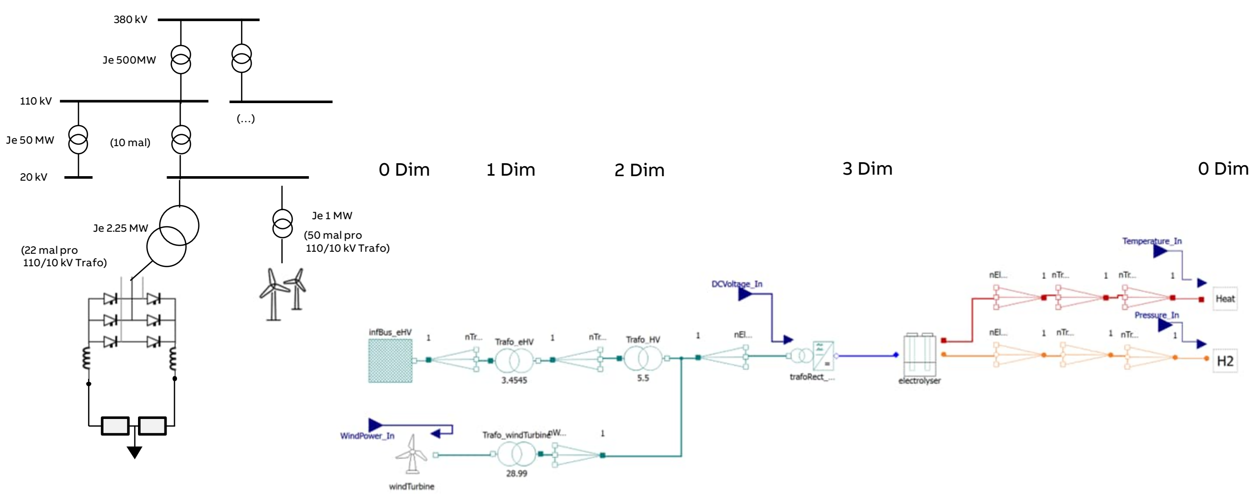
OpenSCALING

Use case: large-scale green electrolysis – multi-dim Modelica arrays



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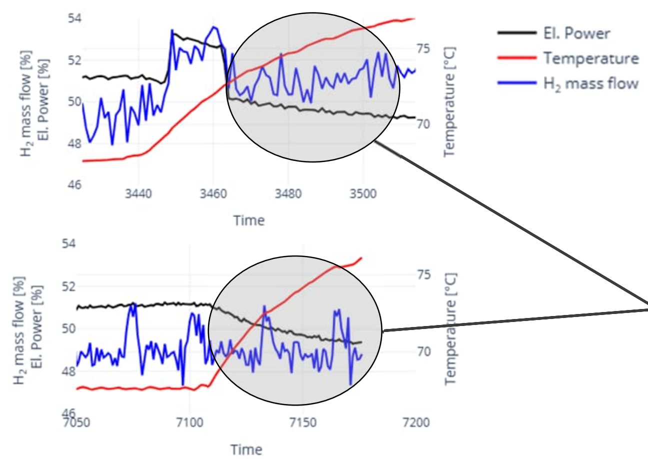
Limitation of physical model

H2 production is driven by power but influenced by temperature too



Affine model used in predictive optimization depends on power (more power = more H_2)

Data shows efficiency increases at high temperatures

Consider temperature effect via neural network for real-time optimization

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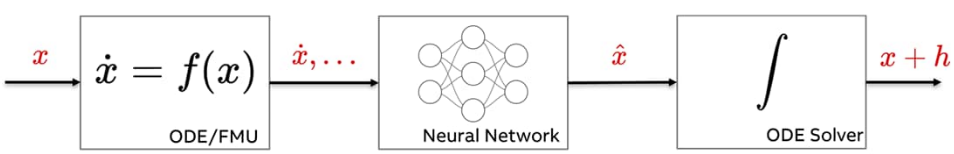
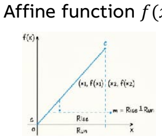
Dynamical Systems

$$\frac{dx}{dt} = f(x, u, t), \quad x(t_0) = x_0$$

Physics-enhanced Neural ODE

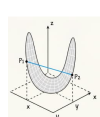


Affine function $f(x)$



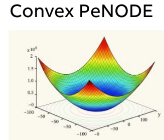
Physical model

Input convex NN



NN-based compensation

Convex PeNODE



Physics-enhanced model

Ensure unique optimization solution

Note: the product of an affine and a convex function is convex only under extra conditions

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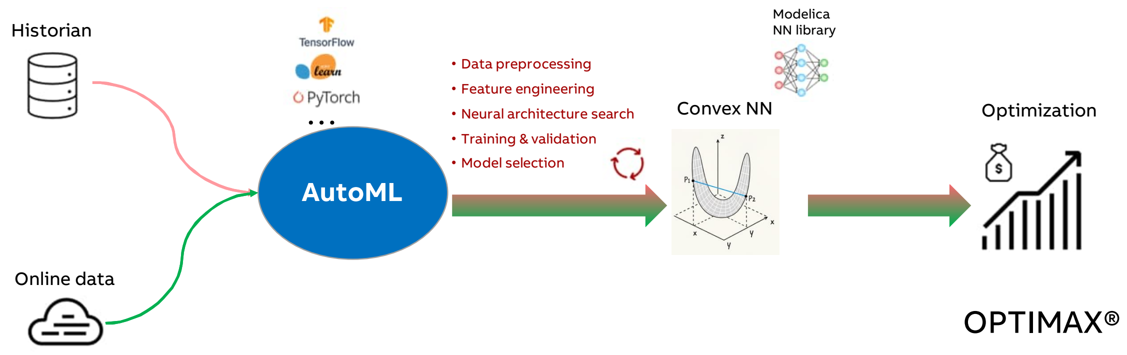
AutoML

First model creation

Continuous improvement



Goal: Automatic Workflow within OPTIMAX Platform

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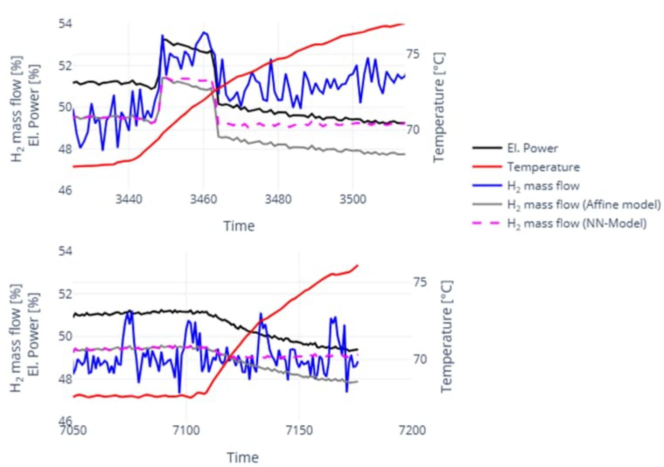
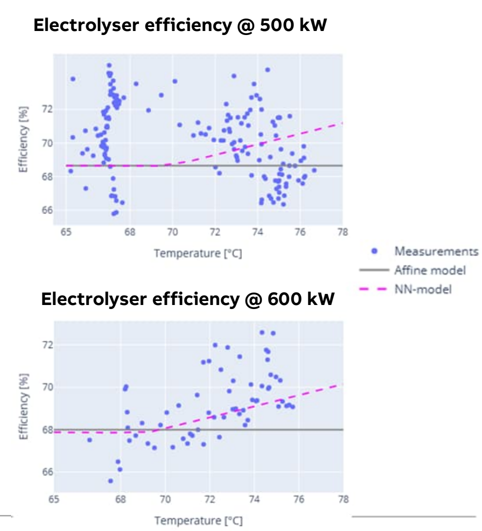
Training results

NN-Correction improves overall model





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Conclusions

OpenModelica proved very powerful for planning and real-time optimization of a large hydrid offshore grid, solving optimal power flow problems in a closed control loop

Using the PowerSystems library, the electrical model is as detailed as with dedicated power flow simulation tools

The OpenModelics C++ runtime generates high performance code for parallel optimization in real-time

The resulting master controller is in commercial operation since several years; operational examples are given

New challenges arise from sector coupling with hydrogen, building a sustainable future based on renewable power

Physics-enhanced Neural ODEs complement physical models with data driven neural networks

A new model building pipeline has been developed within the OpenSCALING project

An example shows its successful application to an enhanced electrolyser model

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