POWER-GEN Europe 2013

R. Franke, H. Schönung, M. Blaumann, A. Frick, S. Kautsch:
Real-time and intraday optimization of multiple power generation units
New trends for optimization of power production

1. The number of power production units significantly increases with the use of renewable energy
2. The power production needs to be re-planned frequently during a day, in order to account for fluctuations
3. The required optimization cycle times reduces from daily planning cycles down to seconds, e.g. for pooling of secondary frequency control
4. The role of human operators changes from being part of the loop to supervision
Traditional system layout
New system layout
## References / Benefits

<table>
<thead>
<tr>
<th>Reference</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal optimization of conventional power plants</strong></td>
<td>• Plant efficiency</td>
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<tr>
<td></td>
<td>• Secondary + Tertiary Control</td>
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<td>• Flexibility with pools / hierarchy</td>
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<td><strong>Combined Heat and Power</strong></td>
<td>• Plant efficiency</td>
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<td>• Secondary + Tertiary Control</td>
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<td></td>
<td>• Trading</td>
</tr>
<tr>
<td><strong>Real-time optimization of pools of biogas plants</strong></td>
<td>• Secondary Control</td>
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<td></td>
<td>• Minute Reserve</td>
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<td></td>
<td>• Direct Trading of renewables</td>
</tr>
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<td><strong>Intraday optimization of municipal power</strong></td>
<td>• Planned Production</td>
</tr>
<tr>
<td></td>
<td>• Direct Trading</td>
</tr>
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<td></td>
<td>• Autarc energy regions</td>
</tr>
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<td><strong>Renewable power feed-in management (EEG Einspeisemanagement)</strong></td>
<td>• Grid stability</td>
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<td>• Compliance with laws</td>
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Reference: Internal Optimization power plant Jänschwalde
Pooling of six 500 MW units

Advantage of Multi-unit optimization

- Exploit communication network between management system and unit control system
- Real-time optimization of set points and secondary frequency control
- Fast and optimal reaction to fulfill production task, incl. gradients and timing of load ramps

Goals:
- Minimize fuel consumption and CO₂-emissions
- Increase flexibility
Graphical model editor
Structuring of mathematical equations / mathematical programs

Für $P_{\text{Soll, Kraftwerk}} = \sum P_{\text{Böcke}} 

\min K_{\text{gesamt, Kraftwerk}} \Leftrightarrow \min \sum (H_a \cdot Q \text{ zugeführt}) \text{ Böcke}!
Simple operation using regular operator graphics
Combined heat and el production

Flexible use of different production units
- Gas turbines
- Boilers
- Steam turbines
- Different fuels

Online-Optimization considering market needs
- Planned production
- Minute reserve
- Secondary Frequency Control
Graphical model editor for plant model (Modelica)
- Formulation and solution of real-time optimization (Dynamic Optimizer)
- Control connectivity through OPC DA

\[
J = - \sum_{Boiler_j}^n c_{NG,j} \dot{Q}_{NG,j} + \sum_{Turbine_j}^m c_{El,j} P_{El,j} \rightarrow \max \dot{Q}_{NG,j}, \dot{Q}_{BFG}, \dot{Q}_{COG}, \dot{Q}_{Oil}, P_{12,j}, m_{Real Stations}
\]

so that:
\[
\dot{Q}_{BFG} = \dot{Q}_{BFG, provided}, \quad \dot{Q}_{COG} = \dot{Q}_{COG, provided}
\]
\[
\dot{m}_{4bar} = \dot{m}_{4bar, demand}, \quad \dot{m}_{1bar} = \dot{m}_{1bar, demand}
\]
\[
0 = F(x), \quad F = \text{Process model with balance equations}
\]
\[
\dot{m}_{Boiler_i, min} \leq \dot{m}_{Boiler_i} \leq \dot{m}_{Boiler_i, max}, \quad i = 1, \ldots, n
\]
\[
P_{Turbine_j, min} \leq P_{Turbine_j} \leq P_{Turbine_j, max}, \quad j = 1, \ldots, m
\]

...
SRL Pooling of renewable biogas plants: system overview

- Redundant Process Database
- Real-Time Optimization
- IEC 60870-5-104 Scanner
- Operation & Management

- Operations Client
- Service Client
- Engineering Client

- Up to 500 production units, typically 500 kW per unit

- 4 Grid Operators

- Internet

- VPN Gateway 1
- VPN Gateway 2

- Next Kraftwerke Engineering Station

- ABB Engineering Station

- Leitwerte Überwachung und Steuerung

- Import / Export for operational management
SRL Pooling of renewable plants: redundant implementation

Results of auctions, availabilities, schedules

IEC 60870-5-104 Scanner

Process DB

Control (Real-time Opt.)

Unit 1

Unit 2

…

Unit 500

IEC 60870-5-104 Scanner

Process DB

Control (Real-time Opt.)

Operation (S+ Office Client)

Import (PGIM)

Export (PGIM)

Reports, e.g. unit commitment

Grid Operator 1

Grid Operator 2

Grid Operator 3

Grid Operator 4

Grid Op. 5 (Test)

SC Request

SC Request

SC Request

SC Request

SC Request Grid Operator 1

SC Request Grid Operator 2

SC Request Grid Operator 3

SC Request Grid Operator 4

SC Request Grid Op. 5 (Test)

Reports, e.g.

Unit commitment

Real-time

Planning

Monitoring
Renewable Energy Feed-In Management

Legal Basis: EEG § 11

Grid operators are allowed to reduce the power of renewable energy plants in case

1. Grid security / stability is jeopardized
2. Priority of renewable energy is granted.
Intraday optimization of municipal power

- Aim: balance production and load
- Exploit storage capacities, e.g. heat buffers, pump stores, electrical mobility
Conclusions

- New system layout with online optimization connected directly to automation networks (either physically or through VPN)
- Mathematical optimization running in control loops
- Simple engineering exploiting Modelica technology
- Human operators take supervisory role
- Increase flexibility of power production, including: secondary control, minute reserve, direct trading
- Always run at economic best point
- Implemented in OPTIMAX PowerFit, now basing on ABB Dynamic Optimization
- Successful references for real-time and intraday optimization