TECHNISCHE UNIVERSITÄT DRESDEN

Security Constrained Dispatch and Transmission Switching:

An Application to the Power Markets of Belgium and the Netherlands

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EE²

Chair of Energy Economics and Public Sector Management

Agenda

1. **Introduction**
    1. **Security Concepts in Power Systems**
    2. **Concept of Transmission Switching**
2. **Model, Data, and Scenarios**
3. **Results**
4. **Conclusions**
5. **Literature**

Introduction

- **Liberalization and restructuring of power markets have led to a focus on the efficient use of existing resources**
  - **Generation processes**
  - **Transmission processes**

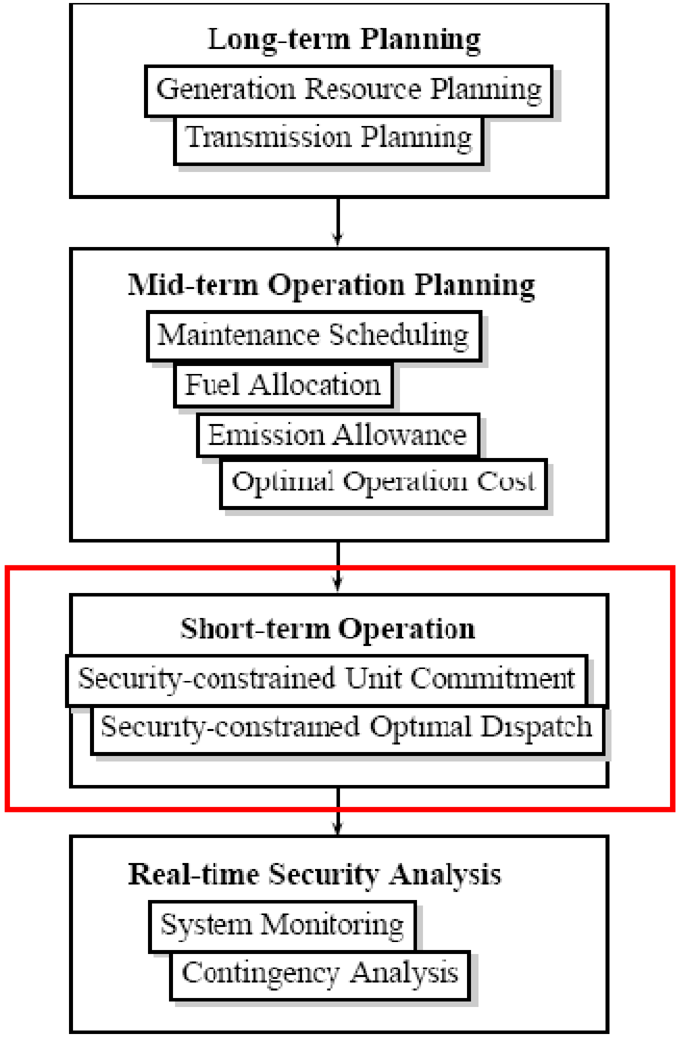
In restructured markets, transmission has to support two functions (Blumsack, 2006)

1. **Reliable power supply**
   - **Security/Reliability is an immanent part of power markets due to technical requirements**
   - **Network redundancies required for reliability but not required for every market realization**
2. **Support increasing market transactions**
   - **Transmission essential for power markets and has to support the entrance of new market participants**
   - **However, long lifetimes of transmission equipment and lead times in transmission investments lead to a focus on the efficient use of existing resources**

→ <u>Investigation of security aspects and flexible network topologies</u>

Security Concepts in Power Systems

- **Power system security is understood as the ability to survive plausible contingencies without interruption of customer service (Morison et al., 2004)**
- **Security aspects need to be considered in different time scales**
- **Interaction of time-scales due to long lifetimes of technical equipment**
- **Focus on short-term operation**
- **Instruments for improving security:**
  - **Security Monitoring**
  - **Contingency Analysis**
  - **Security constrained optimal dispatch (SCOPF)**



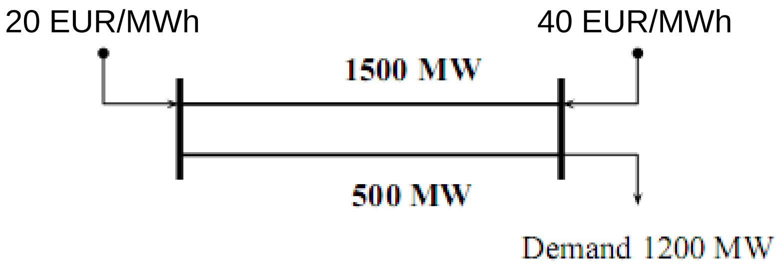
Based on Shahidepour et al. (2005)

Concept of Transmission Switching

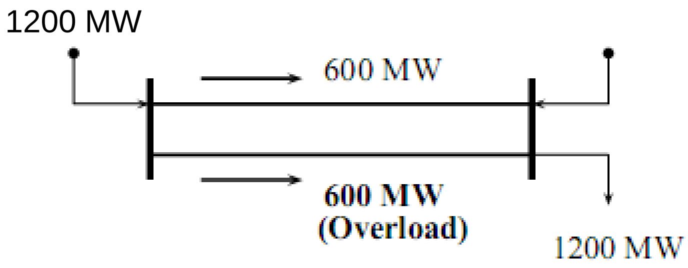
- **Transmission networks are often assumed as static, but the economic or reliability benefit of a transmission line is influenced by system load and remaining topology**
- **Short-run optimization of network topology can increase efficiency**
- **Assuming a flexible network topology can improve several aspects due to "active" load flow management**
  - **Technical aspects: line overloads, loss reduction, improving system security**
    (e.g. Schnyder and Glavitsch,1989; Granelli et al., 2006)
  - **Economic aspects: generation dispatch and costs**
    (e.g. O'Neill et al., 2005; Fisher et al., 2008; Görner et al., 2008)
- **Computational effort limits the application of a completely flexible network, but significant savings can be achieved by switching only a few lines (Fisher et al., 2008)**

Concept of Transmission Switching (contd.)

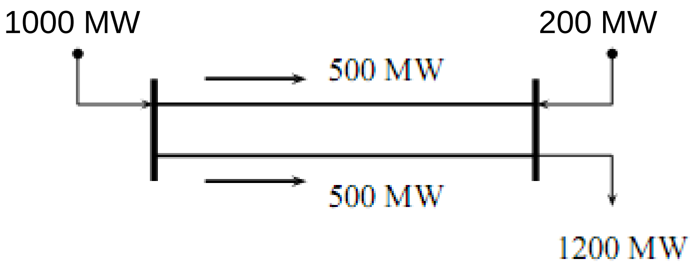
1. Initial situation



2. Optimal dispatch (infeasible!)

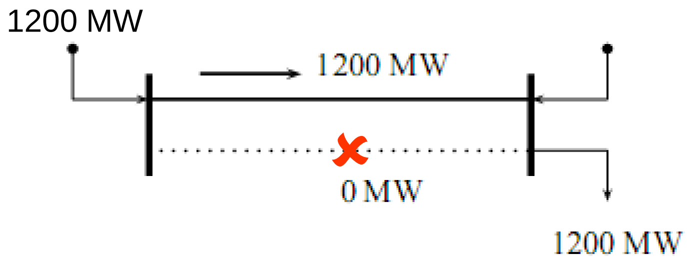


3. Optimal dispatch with re-dispatch



Costs = 1000*20+200*40 = <u>28000 EUR/h</u>

4. Optimal dispatch with switching



Costs = 1200*20 = <u>24000 EUR/h</u>

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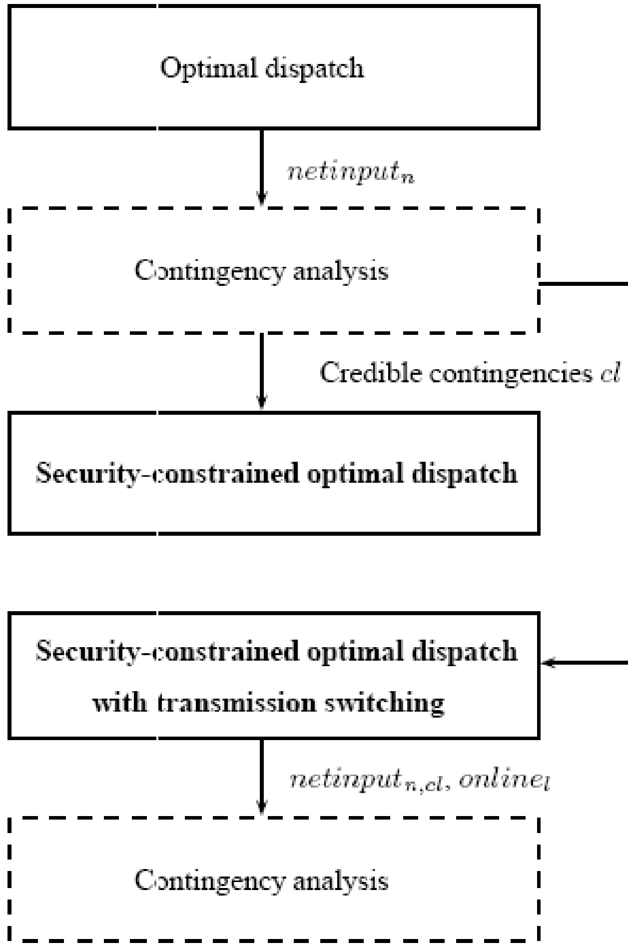
Model, Data, and Scenarios

- DC load flow approximation
- Contingency analysis
  - Outage of one line circuit (N-1 criterion)
  - Calculation of outage flows through equality constraints
  - Overloads above 110% considered as credible contingencies
- Consideration of credible contingencies in dispatch calculation through 'current injection method' (SCOPF)
- Consideration of 2-4 switching actions in the generation dispatch optimization



Model, Data, and Scenarios (contd.)

- **Contingency evaluation and determination of control actions through security constrained dispatch model (*N1*$_{l,cl}$)**
- **Implementation of network flexibility (*online*$_l$)**

$$\min_{g_{n,s}, online_l} \quad costs = \sum_{n,s} mc_{n,s}\, g_{n,s}$$

$$\sum_s g_{n,s} - q_n - netinput_{n,cl} + windgen_n = 0 \quad \forall \quad n, cl$$

$$netinput_{n,cl} - \sum_l Incidence_{l,n}\, lineflow_{l,cl} = 0 \quad \forall \quad n, cl$$

$$lineflow_{l,cl} - \sum_n H_{l,n}\, \Theta_{n,cl} - (2 - online_l - N1_{l,cl})\, M \leq 0 \quad \forall \quad l, cl$$

$$lineflow_{l,cl} - \sum_n H_{l,n}\, \Theta_{n,cl} + (2 - online_l - N1_{l,cl})\, M \geq 0 \quad \forall \quad l, cl$$

$$0 \leq g_{n,s} \leq g_{n,s}^{max} \quad \forall \quad n, s$$

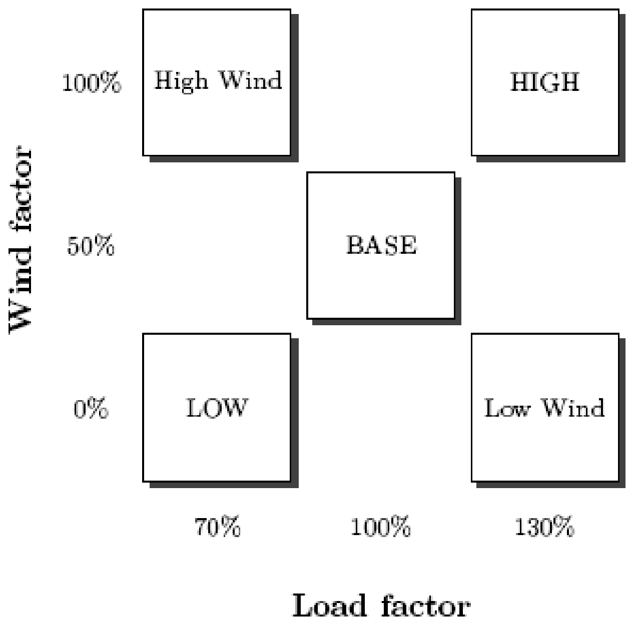
$$-P_l^{max}\, online_l\, N1_{l,cl} \leq lineflow_l \leq P_l^{max}\, online_l\, N1_{l,cl} \quad \forall \quad l, cl$$

$$\sum_l (1 - online_l) \leq maxswitch$$

$$online_l = \{0, 1\}$$

Model, Data, and Scenarios (contd.)

- **Derived static model is applied to the power markets of Belgium and the Netherlands**
  - **112 nodes**
  - **241 transmission circuits (122 circuits available for switching actions)**
  - **238 GW thermal capacity, 24 GW wind generation capacities**
  - **143 GW hourly demand**
- **Calculation of a <u>hourly</u> generation dispatch and switching actions for considered scenarios**



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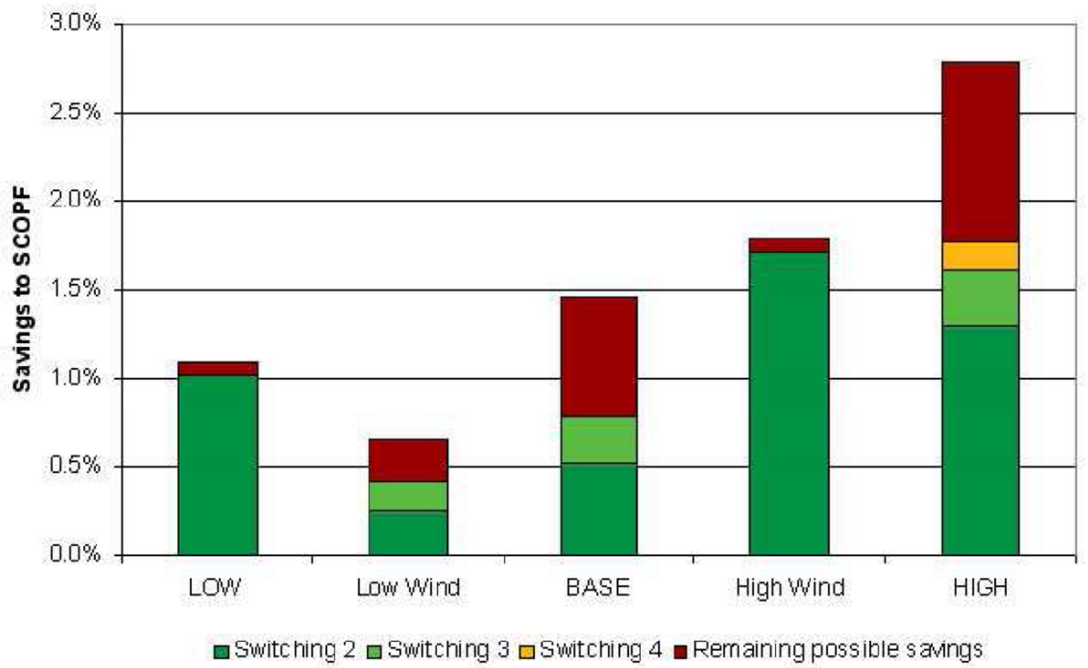
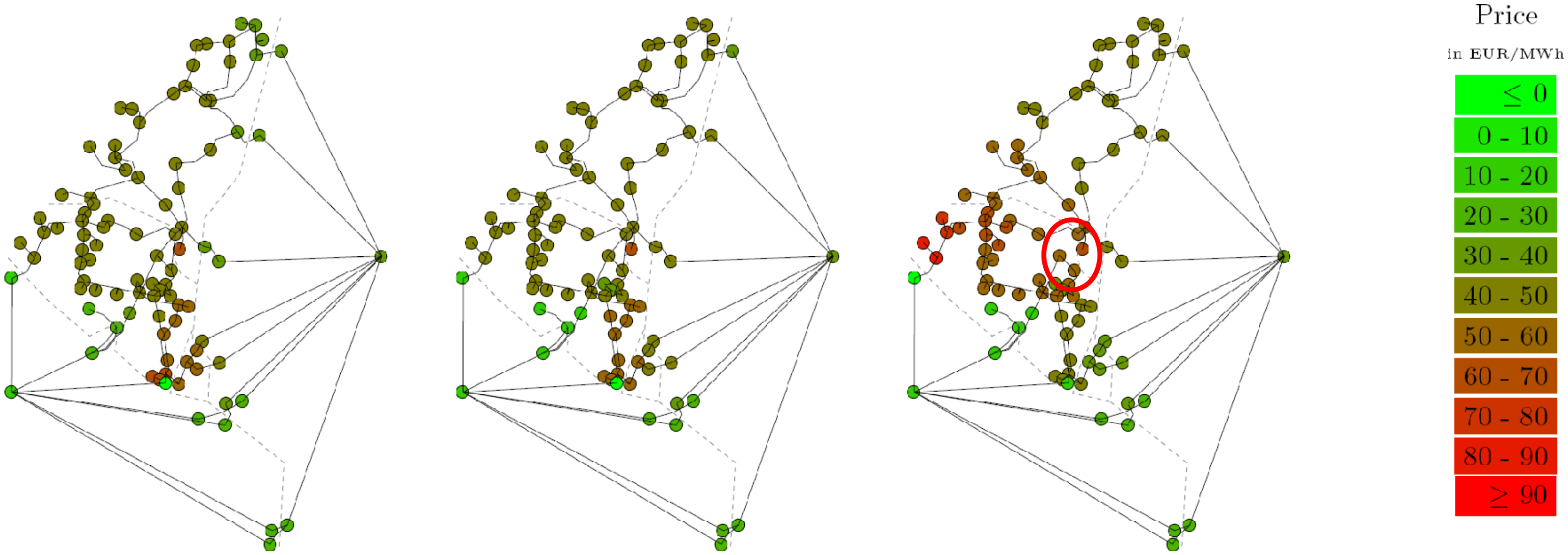
Results

- **Contingency analysis & SCOPF:** 5-7 credible contingencies cause re-dispatching of cheap power plants esp. in France through more costly generation units → cost increase between 0.60% and 1.25%
- **Transmission Switching:** Flexibility of the network topology results in significant generation cost savings and can reduce the cost increasing impact of security constraints → possible cost reductions up to 2.8% in the HIGH scenario



Results (contd.)

- **BASE scenario:**
  - **Switching actions take place in already congested areas (Belgium)**
  - **Switching of two lines results in a shift of congestion due to reduction of loop flows**
  - **Import esp. from France is increased due to load flow management**
  - **Regional effects on prices**



(a) OPF (b) SCOPF (c) SCOPF & Switching

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Conclusions

- Implementation of security constraints (N-1 criterion) increase generation dispatch costs due to reduced power flow limits → re-dispatching of cheap power plants

- Transmission switching significantly reduces generation dispatch costs due to ‘active’ load flow management, but (only) up to 2.8%
- Significant cost savings can already be achieved by switching of only a few lines

- Security constraints are considered in the optimization, but further research necessary to completely ensure security

- Time demanding optimizations currently hinder application of a complete flexible topology to large scale systems

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Thank you very much for your attention!
Any questions or comments?

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