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Vasily Sharipov, Alexey Minin, Ilya Mokhov
Siemens Corporate Technology Russia
Global Technology Field **Self-Organization and Model Predictive Control**

A Protection Strategy for Power Grids Equipped with Siemens Vacuum Reclosers

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Introduction

Smart Grid concept is in focus at **Siemens AG** as one of the largest industrial and energy automation companies worldwide.

The goal of the presentation is to describe particular idea we had during Smart Grid project execution.

Outline

- Smart Grid in Siemens 3
- Idea: online topology optimization 5
- Algorithm 8
- Results of simulation 23
- Conclusions and Perspectives 27
- Contact 28

Smart Grid in Siemens

Energy sector of Siemens AG

Energy sector provides complete hardware/software solutions for external customers. There is a research group at Energy Automation division concentrated on the Smart Grid initiative.

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Lighthouse project at Siemens Corporate Technology

There are several big projects corresponding to major technologies within Siemens CT called lighthouse projects. One of these projects is Smart Grid. One of the goals of this project is to develop control strategies for power grids with many renewable sources.

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Idea: online topology optimization

- Smart Grid in Siemens 3
- **Idea: online topology optimization 5**
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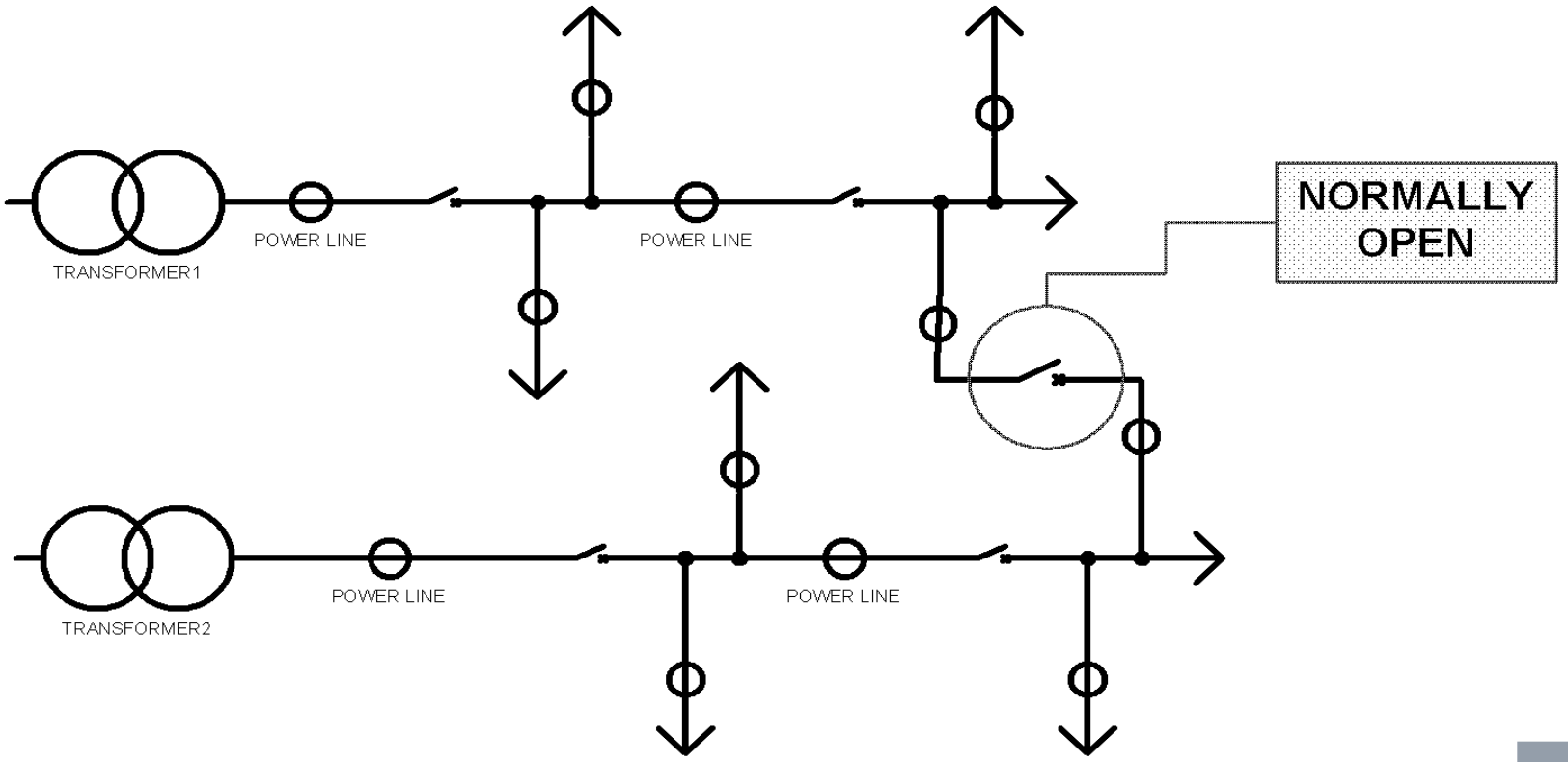
Idea: online topology optimization

Motivation

- Growing complexity of distribution power network
- Structure of distribution power network is changing
- Local control of breakers may not be sufficient
- Modern technologies like phasor measurement units are available

Idea: online topology optimization



Algorithm

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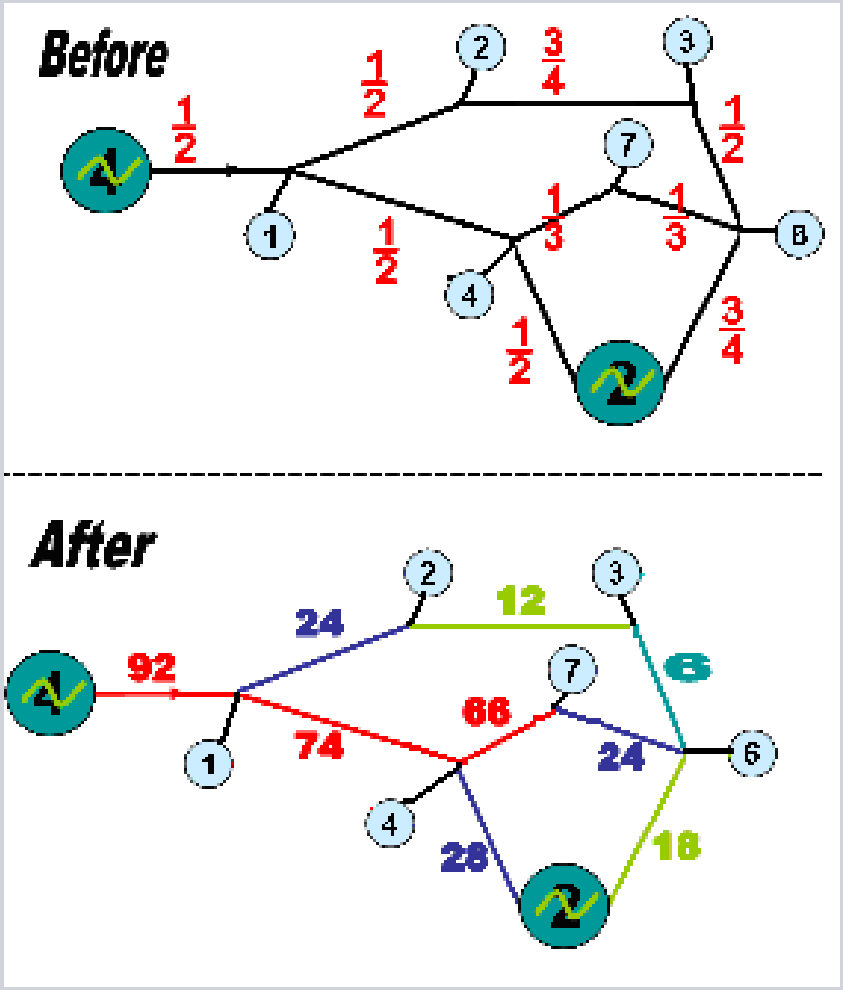
NLIC algorithm

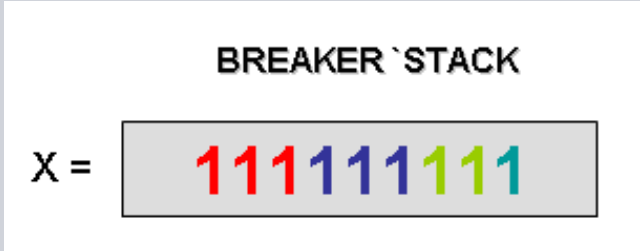


Network line importance calculation

- Each generator and load is set the importance value
- The shortest electrical path for each generator-load pair is calculated
- The product of generator and load importances is propagated through the path and summed up for each power line
- Resulting number for each power line indicates the importance of one

Functional to be optimized

$$\begin{cases} F(X) = \sum_i I_i \times X_i \\ X_i = 0,1 \end{cases}$$



Functional is the sum of importances of closed power lines able to conduct electricity. The goal is to maximize it, i. e. to close as much breakers as possible keeping the most important consumers connected to the network after the fault.

Functional depends on the breaker stack, i. e. on the positions of breakers. Constraint is the power system stability requirement.

Power network state estimation

Stability of new configuration

- Offline modeling of the power network under different conditions -> identification of safe states
- Approximation of safe state space within one of universal classifiers
- Online stability check: based on **synchronized** measurement data trained classifier can identify which breaker can be opened or closed

Classifiers

- Neural Cloud
- Kohonen map

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Taboo search

Features of the taboo search algorithm

- One of the most popular algorithms for integer optimization
- Simple implementation
- Constraints are taken into account within taboo list
- Applicable for high dimensional problems
- Finds local minima

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Taboo search implementation

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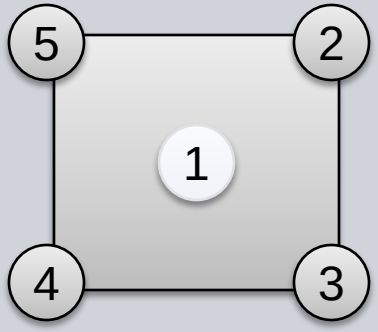
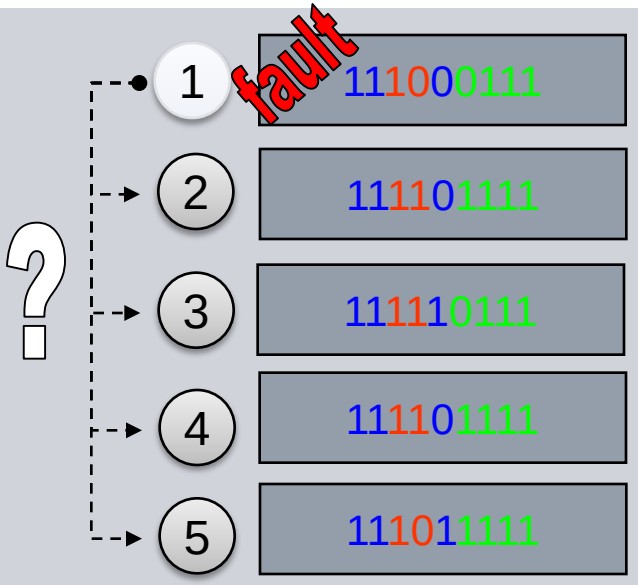
Taboo search implementation



Tabu list



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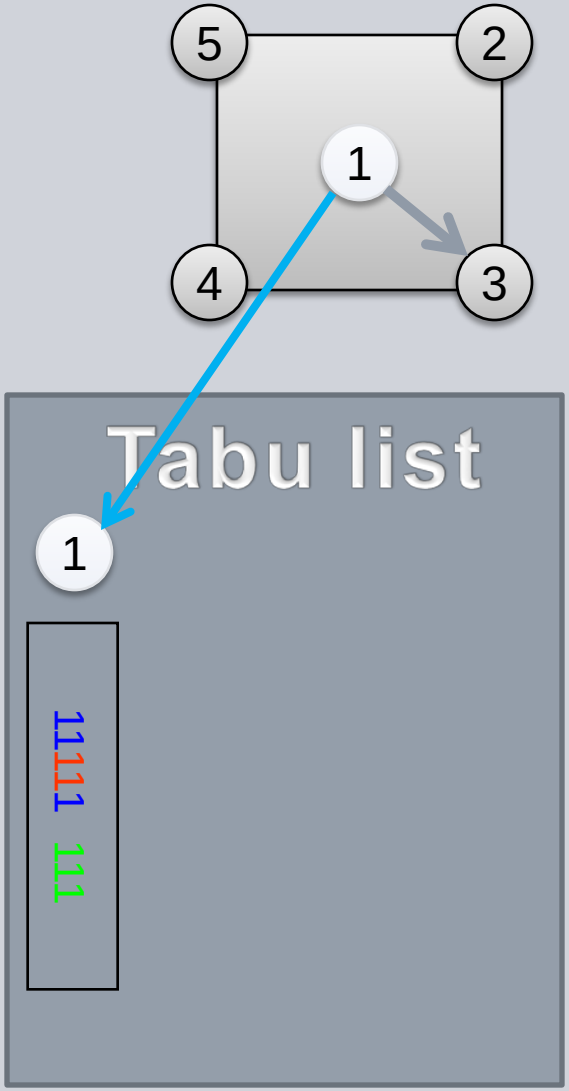
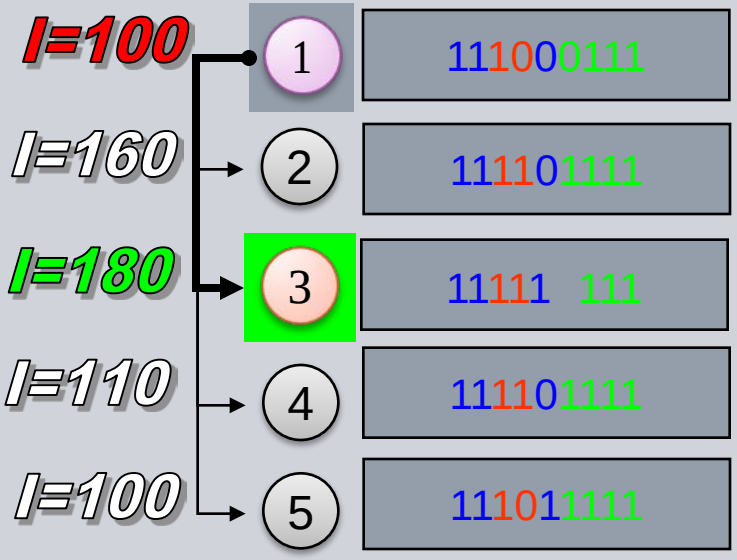
Taboo search implementation





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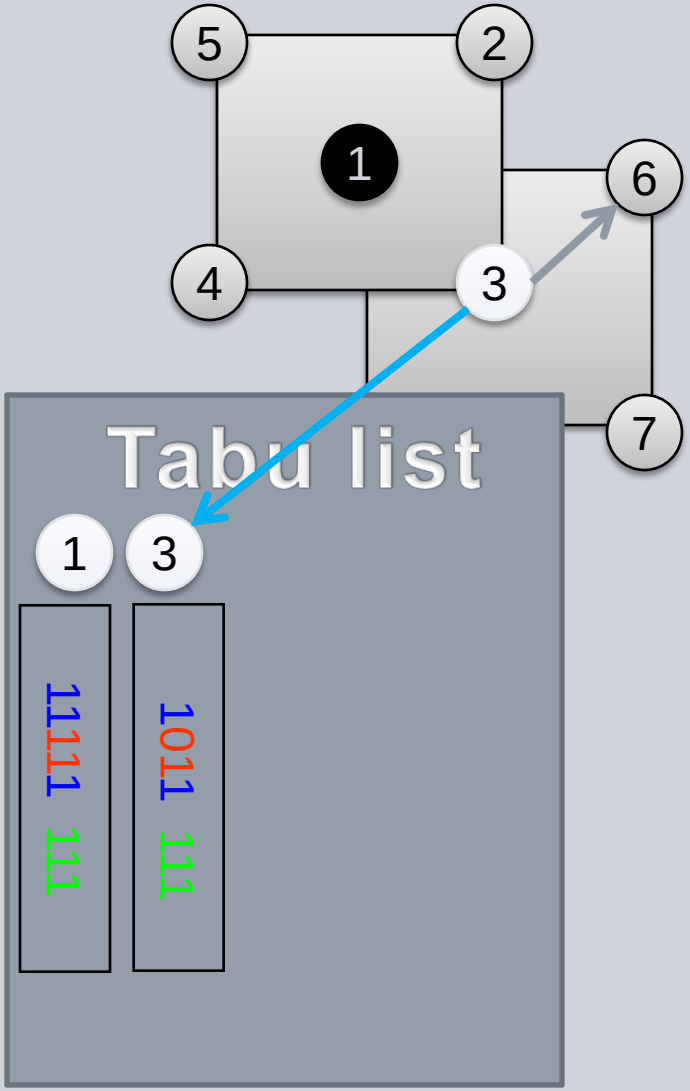

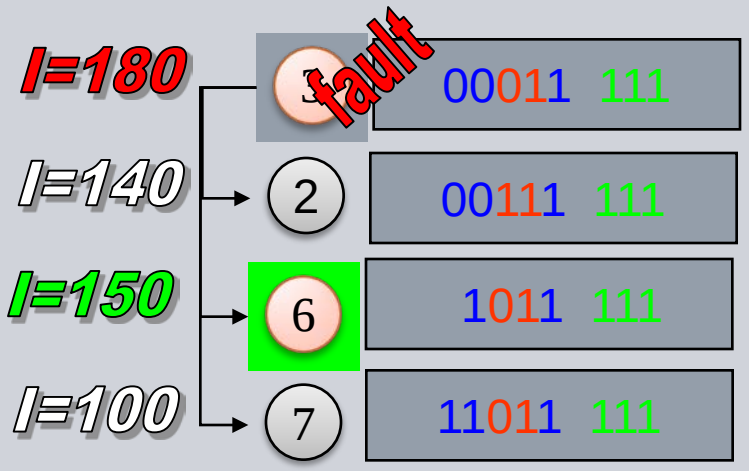

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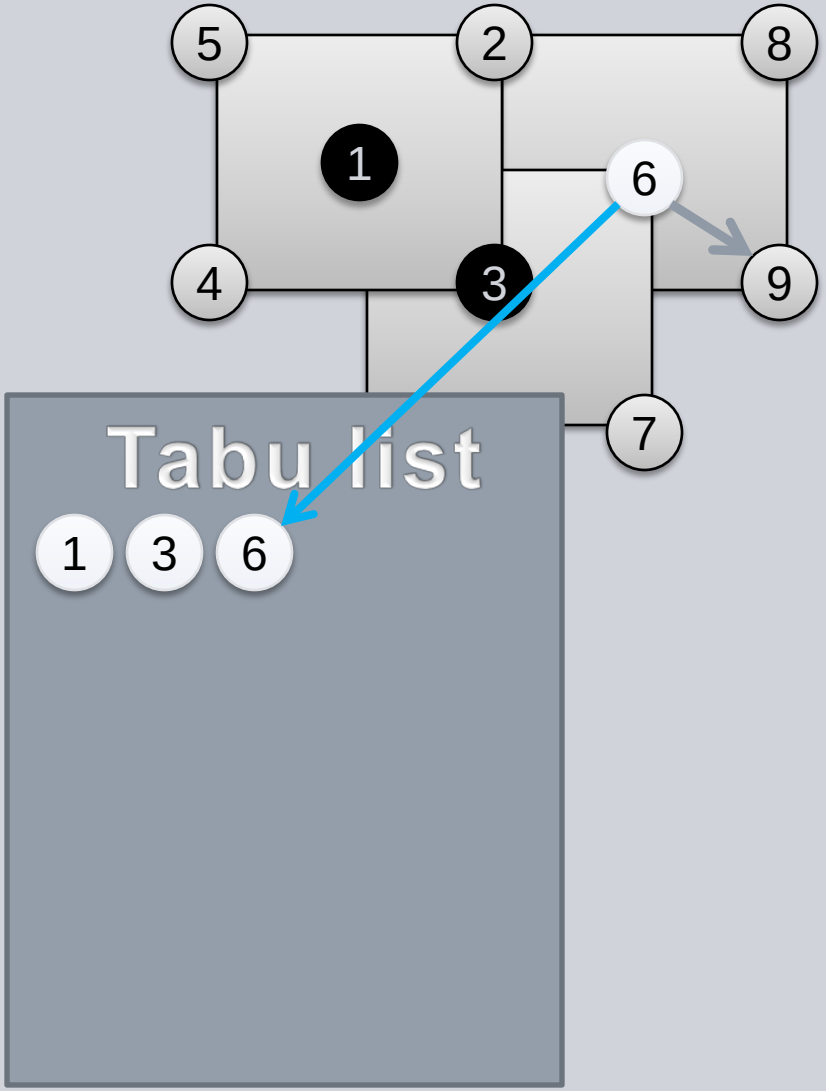

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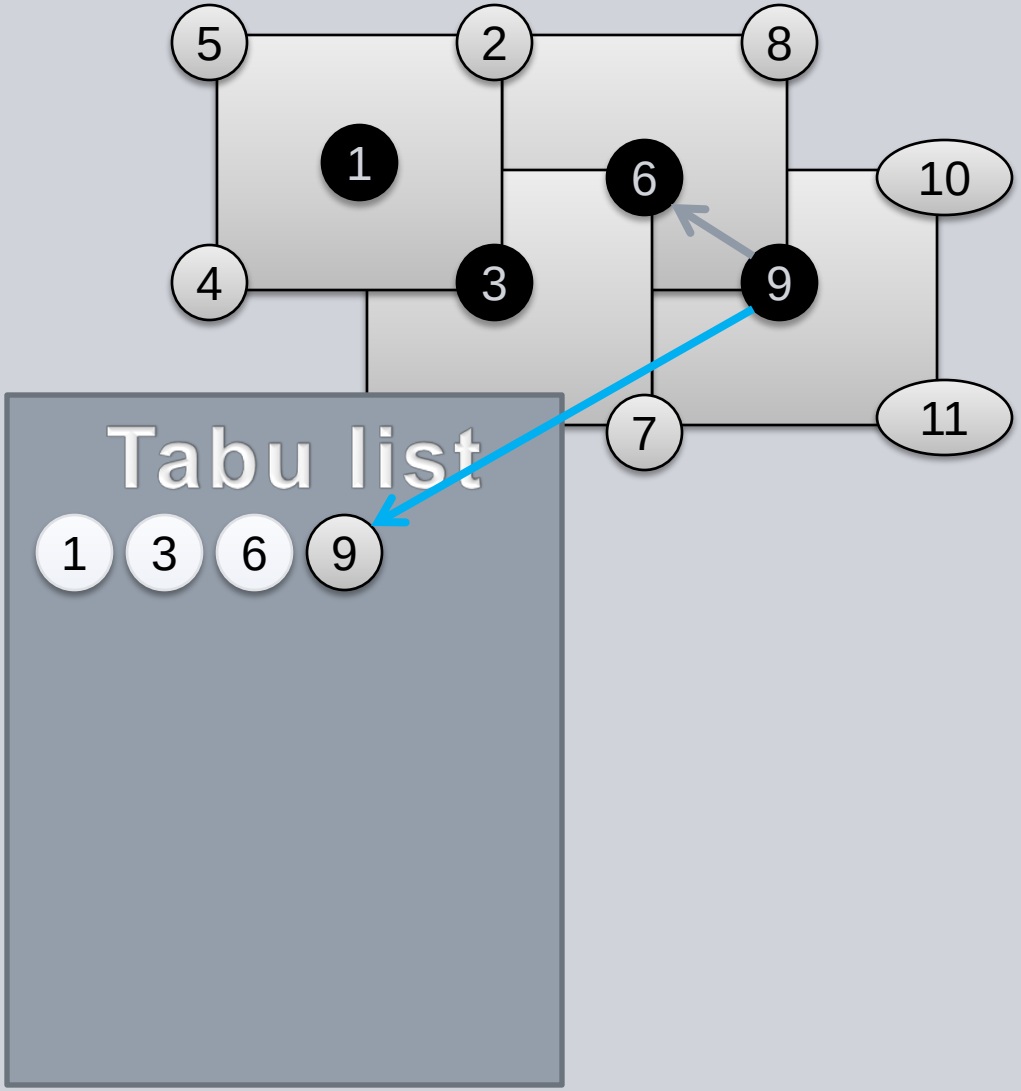
Taboo search implementation



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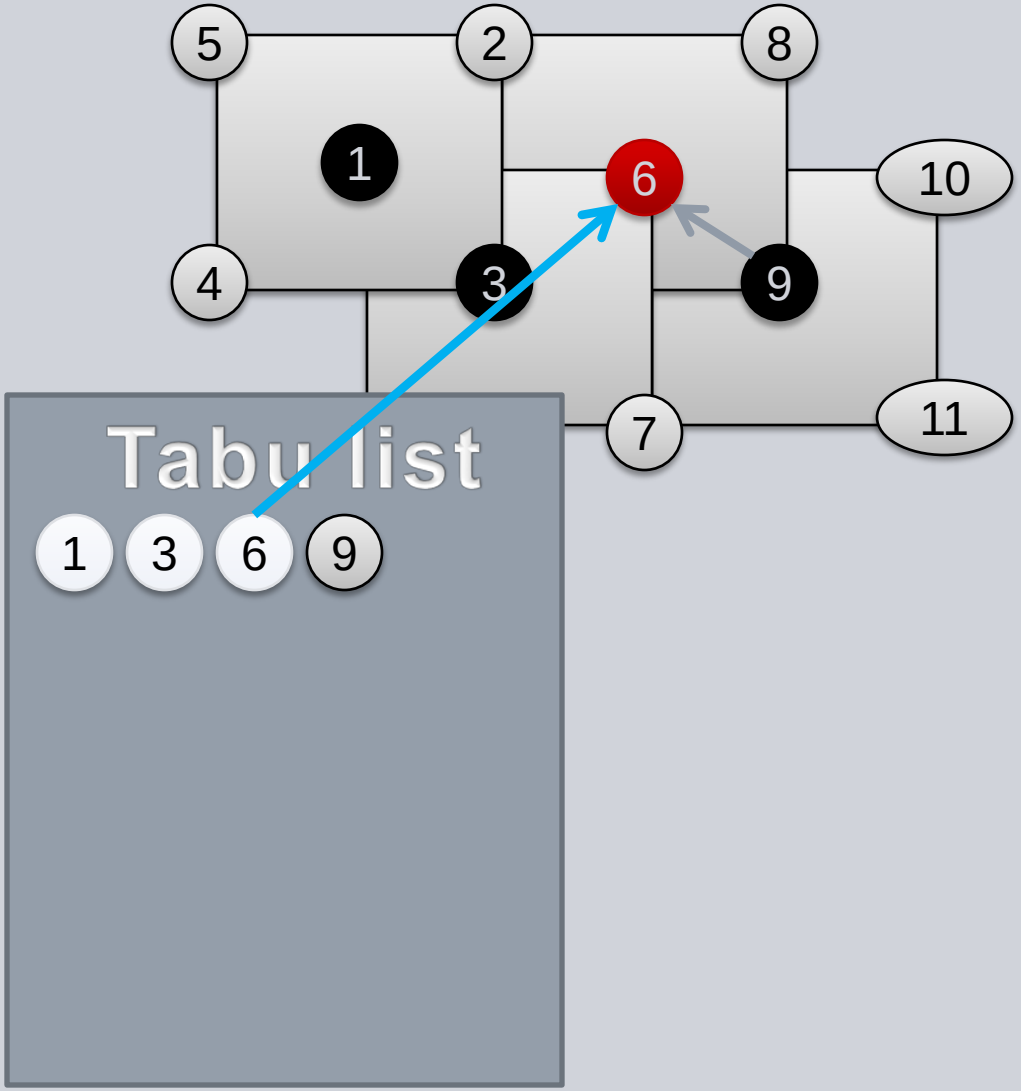

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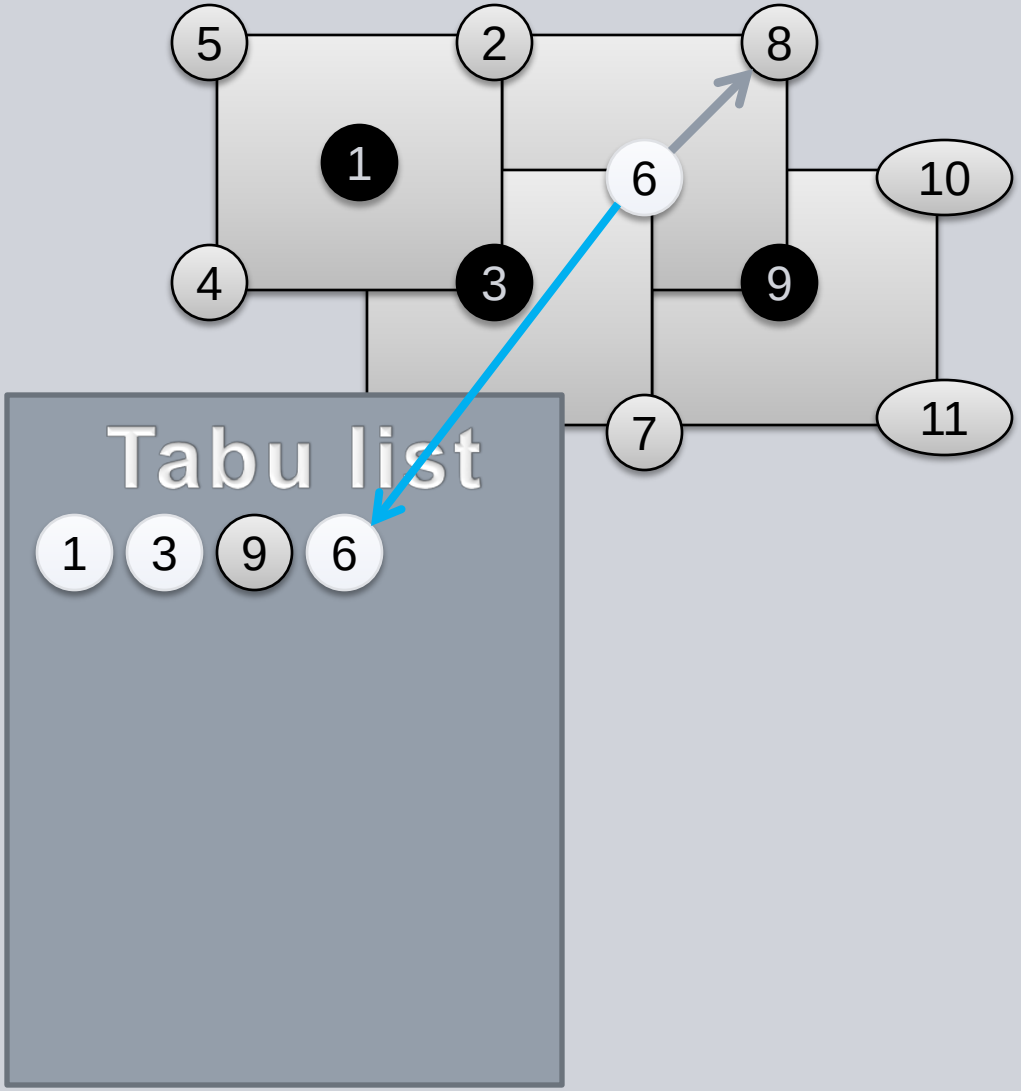

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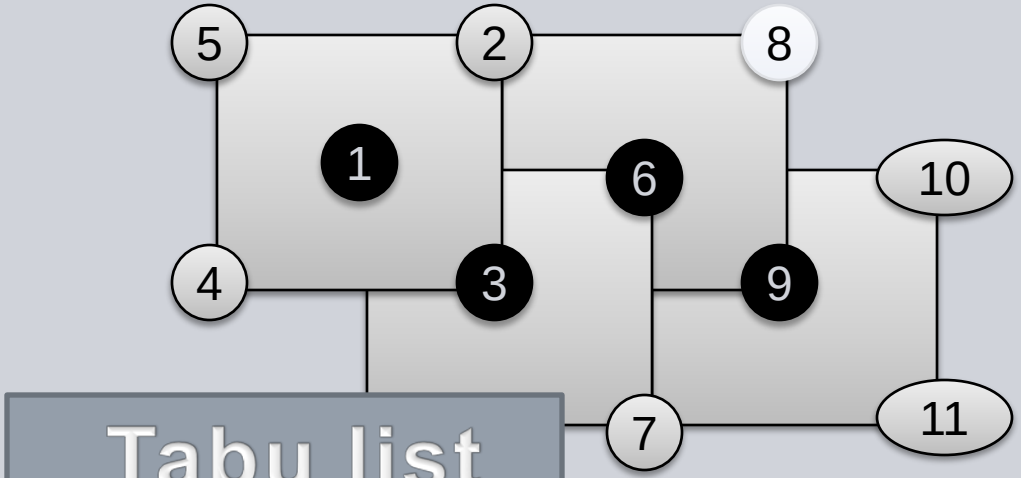

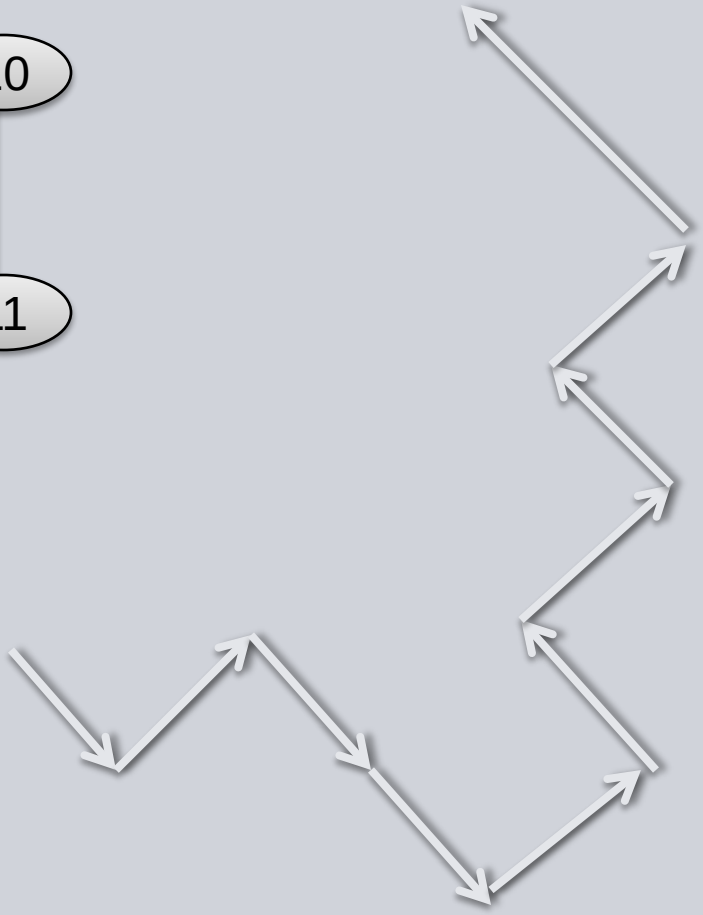

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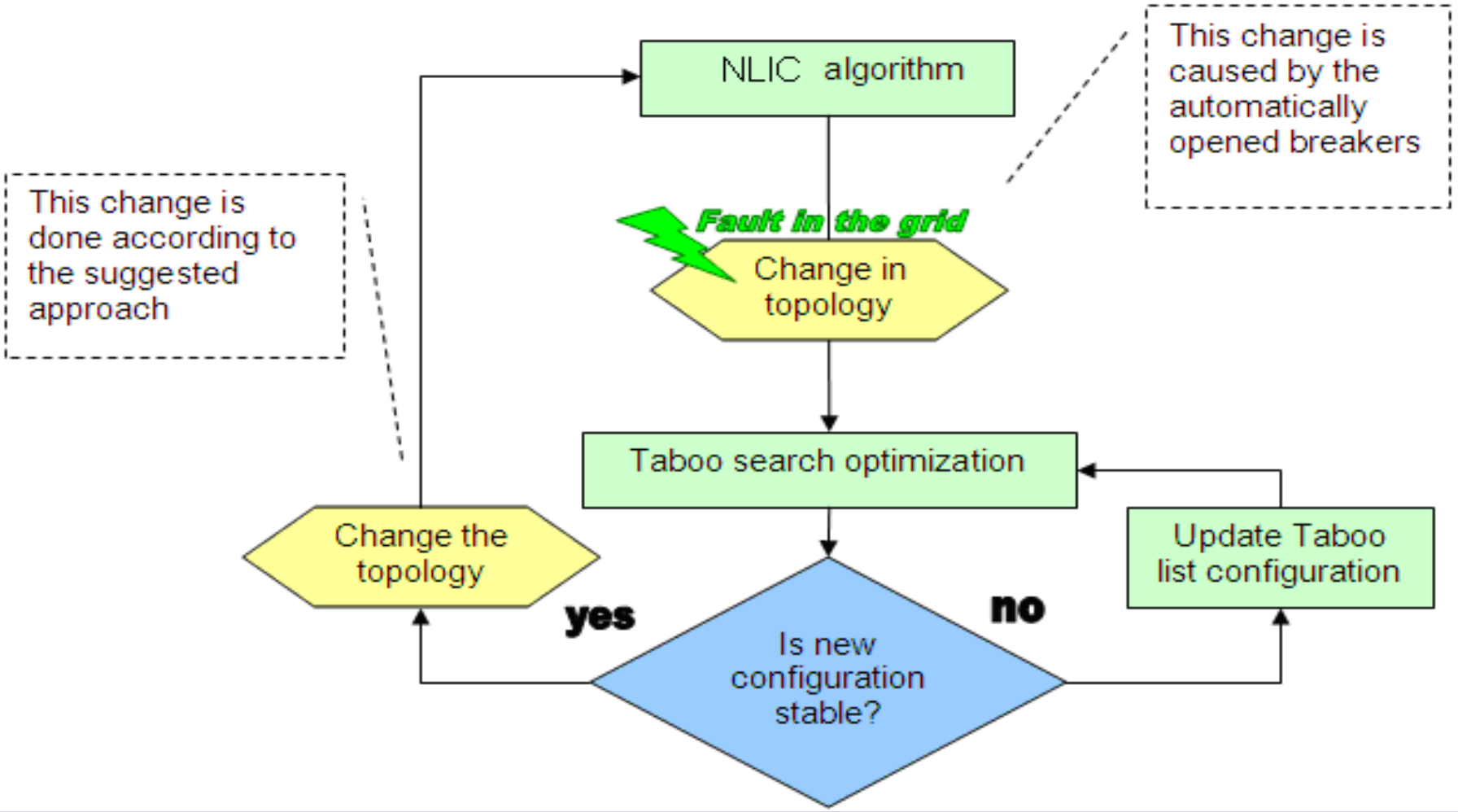
Scheme of the algorithm



Results of simulation

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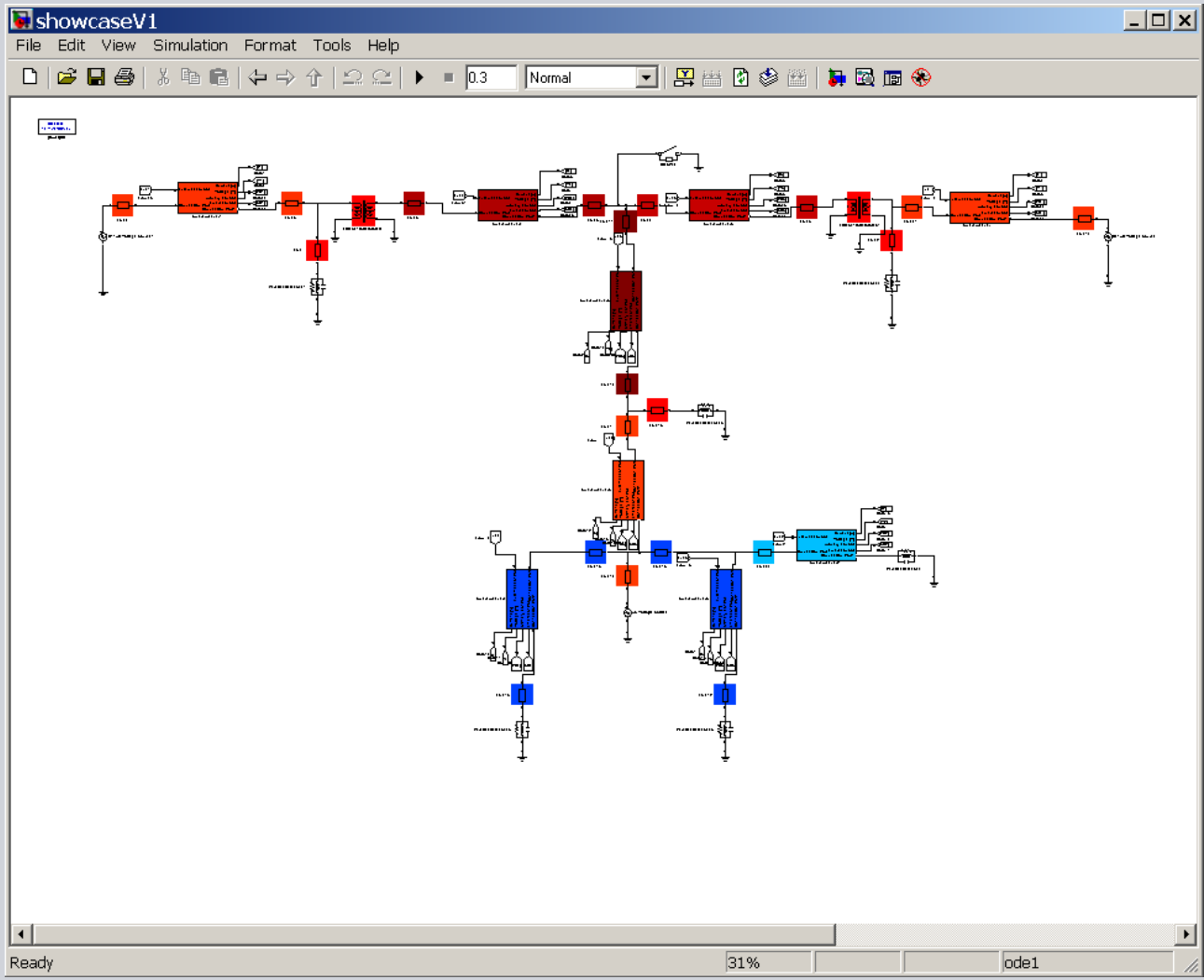
Results of simulation

Simulation setup

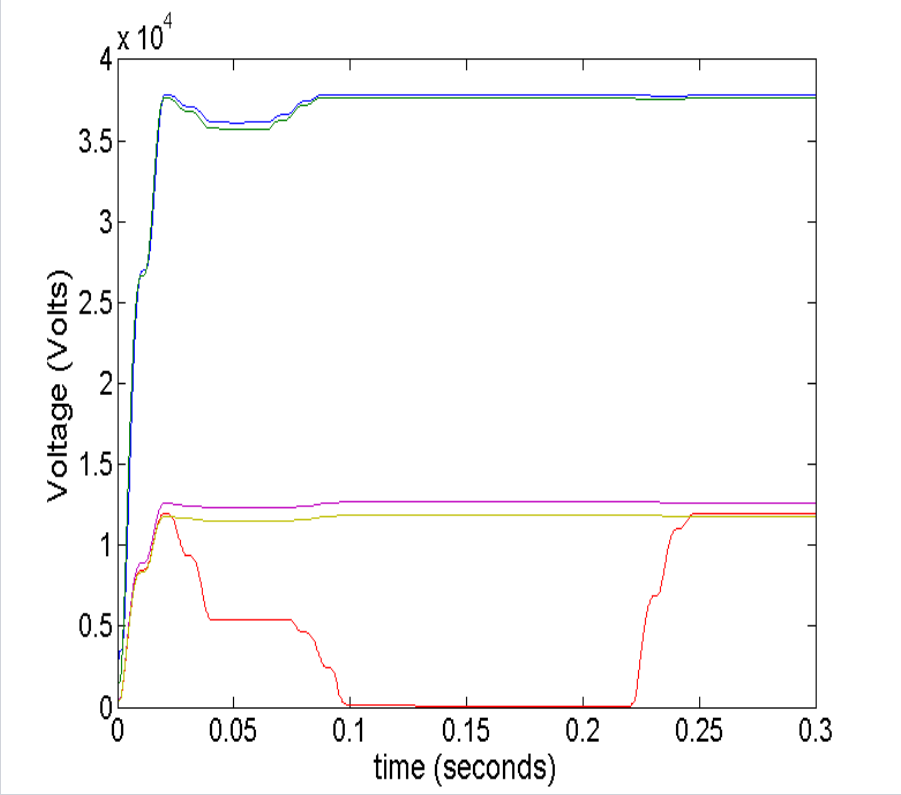
- Simulation tool: Matlab Simulink SimPower
- Simulated system: 2 generators, 2 transformers, 6 loads
- Breakers: 9 controlled reclosers acquiring measurement data
- Nominal voltage: 38 / 12 kV

Simulated power system

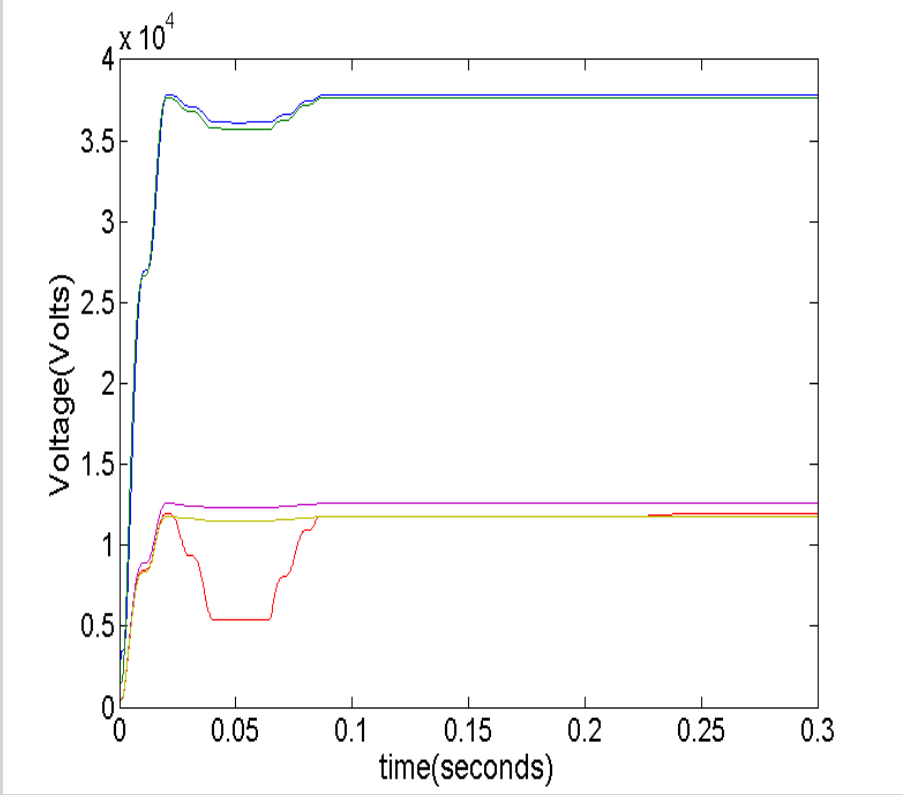
Different regimes of power network (according to daily load profile) have been simulated with different positions of breakers.



Load voltages



Uncontrolled case: reclosers operate according to their local setup



Controlled case: reclosers are controlled via central computer

Conclusions and Perspectives

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Conclusions and Perspectives

Conclusions

- Coordinated breaker actions can be an effective tool for improvement of power grid operation
- Protection of a power grid is possible only with fast and robust communication (via power line?) with PMUs and breakers
- Trained classifiers can be substituted by some expert systems

Perspectives

- Improvement of power quality because of better power balance in the grid
- Use of phasor measurement data for control purposes
- Involving of power line communication

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