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Age-dependent & multi-load reliability analysis in transmission systems

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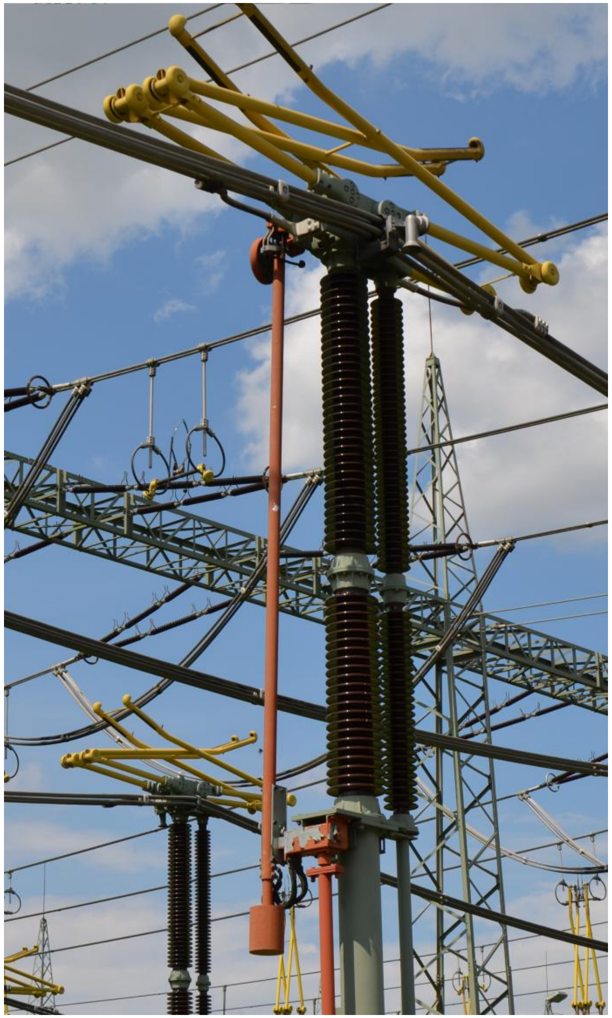

Motivation

Technical aspects

- Higher network utilization
- Availability of the transmission system

Financial interests

- Liberalization of the energy market
- Achieve profit
- Limited billable fees

Reduce network risk by constant maintenance costs with risk based maintenance

- Exact determination of individual asset risk
  - Multi-load reliability analysis
  - Age-dependent outage values

Structure of the transmission system model
Overview

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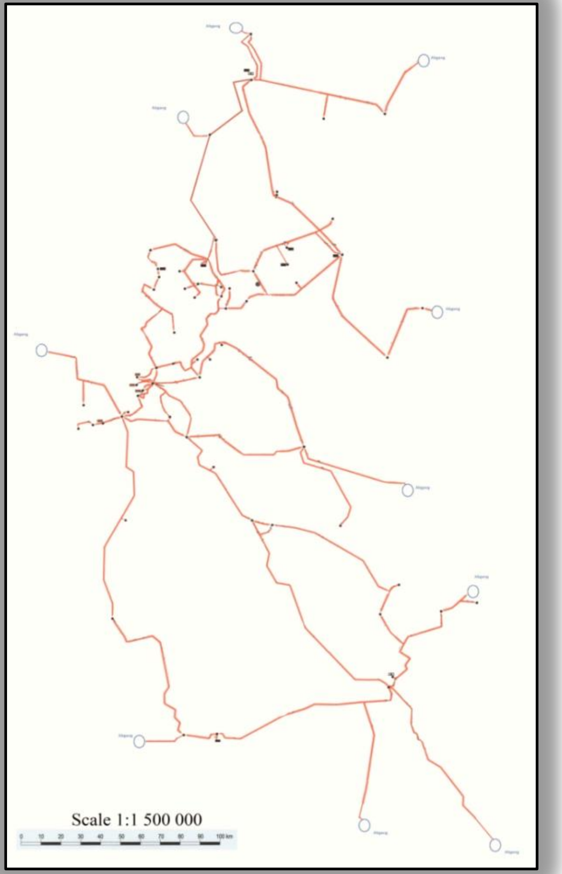
- Large part of the transmission system from a TSO in Germany

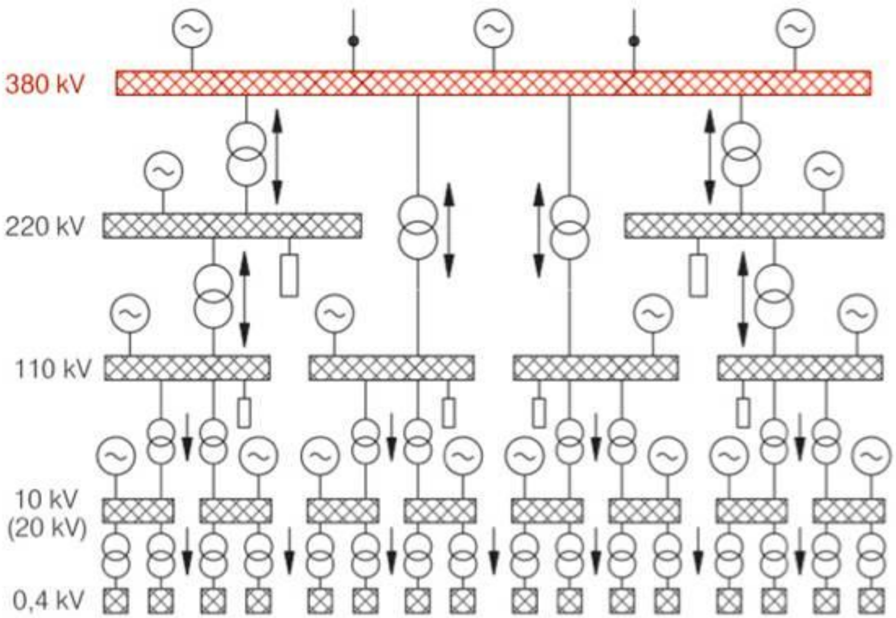
- The model includes this voltage levels:

  - 380 kV transmission system
  - 220 kV transmission system
  - 110 kV network groups



380 kV overhead line network

Structure of the transmission system model
380 kV transmission system



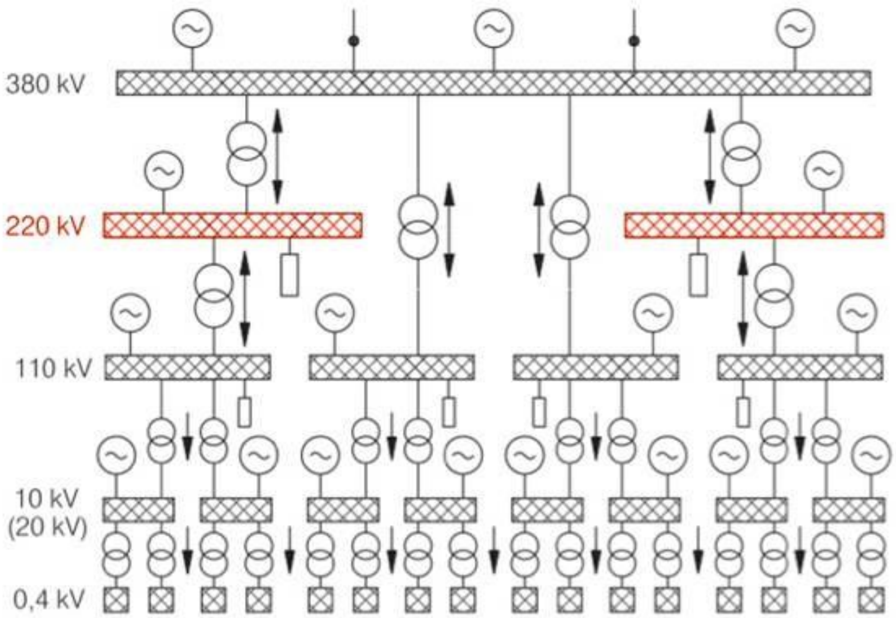
Detail level:

- Substations & busbar configurations
- Switch positions
- Power plant units & transformers
- Length of overhead lines
- Connection points to other TSOs

Element	Number of Elements
Bus bar	145
Center break disconnector	263
Circuit breaker	337
Generator	30
Overhead line	4453 km
Pantograph disconnector	952
Power transformer	380/110kV: 78 380/220kV: 25

More detailed modeling is difficult.

Structure of the transmission system model
220kV transmission system



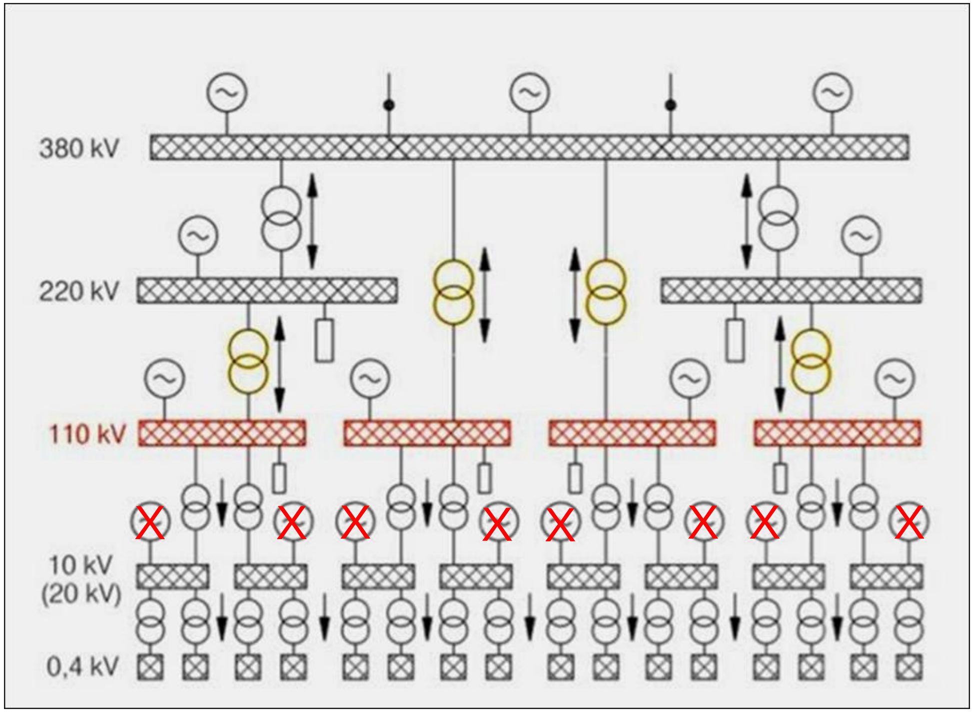
Detail Level:

- Length of overhead lines
- Power plant units
- No substation layout
- No reliability data for assets

Modeling necessary for load flow in 380 kV system

Only modeled structurally.

Structure of the transmission system model 110kV sub-transmission network groups

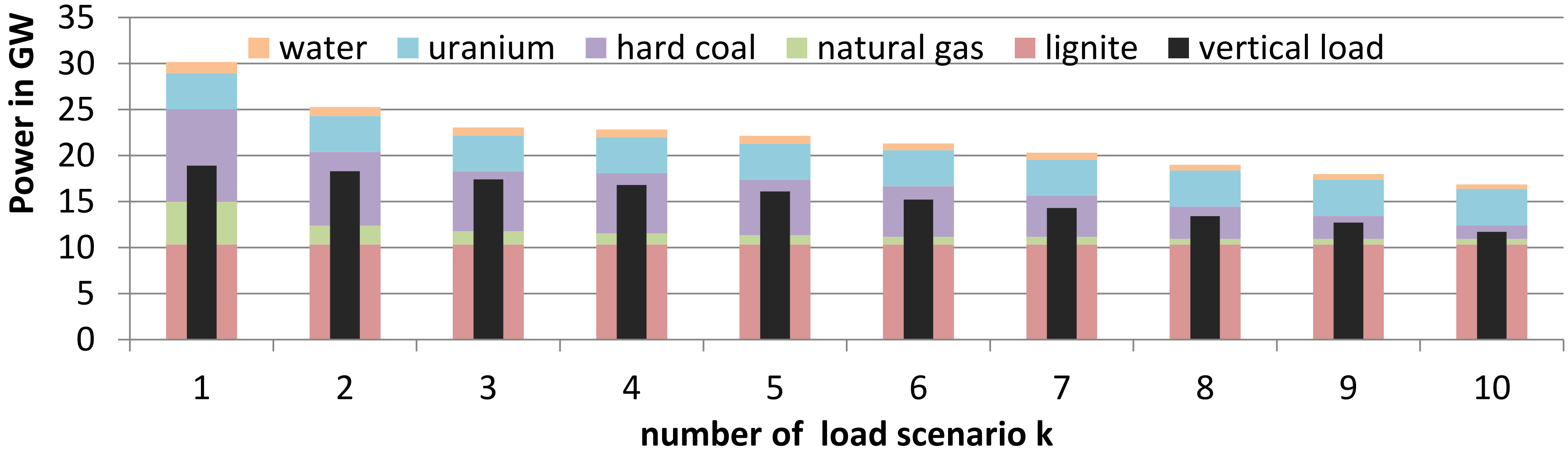


Detail Level:

- Coupling transformers from 380 kV & 220 kV
- Load aggregated as loading of coupling transformers
- Infeed of power plant units disregarded

34 Utility network groups
8 industrial network groups

Load & power plant scenarios



- All common network states within one year adopted.
- Surplus power is transferred into neighboring transmission systems.
- Power plant power gradients are considered in the model

Reliability & Availability analysis for all ten load scenarios

$T_{ND}(n,k)$ non-delivered outage duration in h
$P_{ND}(n,k)$ non-delivered power in MW

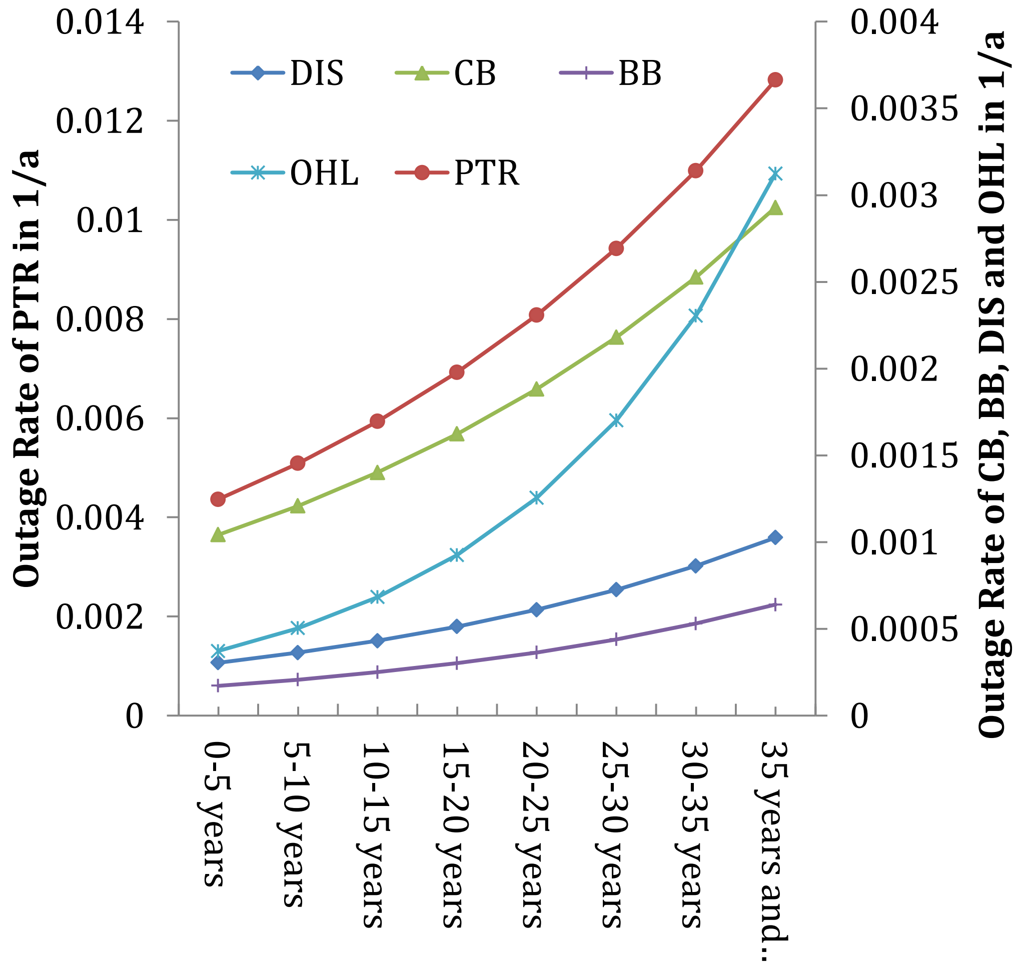
$T_{NS}(n,k)$ non-supplied outage duration in h
$P_{NS}(n,k)$ non-supplied power in MW

Values for power plants

Type of power plant	Load gradients in % per minute	Share of auxiliary power in %	Number of power plant units	Installed gross power in MW
Hard coal	2 -4	7 – 10	18	10038
Lignite	1.5 – 2.5	10 - 16	27	8599
Gas turbine	25	2 - 4	1	112
Combined cycle	5	4 - 6	9	6286
Nuclear	10	4 - 5	3	3925
Pump storage	100	8.5	1	1096

Reliability values

Element	Outage rate H in [1/a]	Outage duration T in [h]
Bus bar	0.00032	6.35
Center break disconnector	0.000513	67.63
Circuit breaker	0.001473	64.69
Overhead lines [a]	0.001562	5.34
Selector switch disconnector [b]	0	0
Power transformer	0.006411	65.99

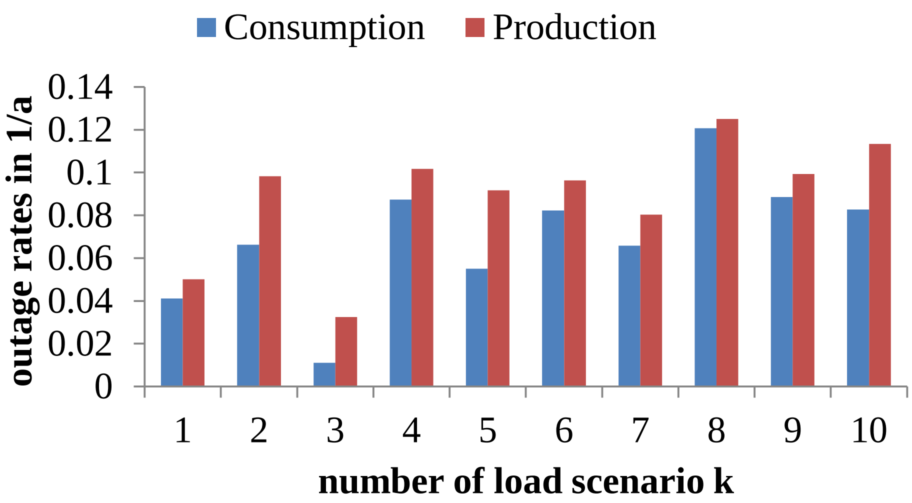


Results: outage rates

$$H_C = \sum_{n=1}^{m} H_n \cdot \Theta(W_{C,n}) \quad (1)$$

$$H_P = \sum_{n=1}^{m} H_n \cdot \Theta(W_{P,n}) \quad (2)$$

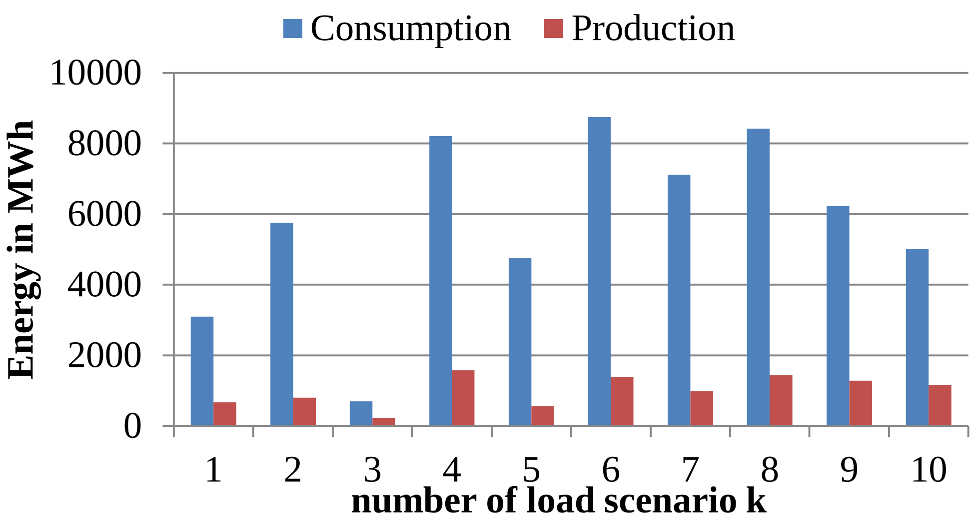
H_n	outage rate of the individual asset in 1/a.
$W_{C,n}$	non delivered energy caused by the individual asset *n* in MWh.
$W_{P,n}$	non feed in energy of power plants caused by the individual asset *n* in MWh.
n	identification number of the individual asset.



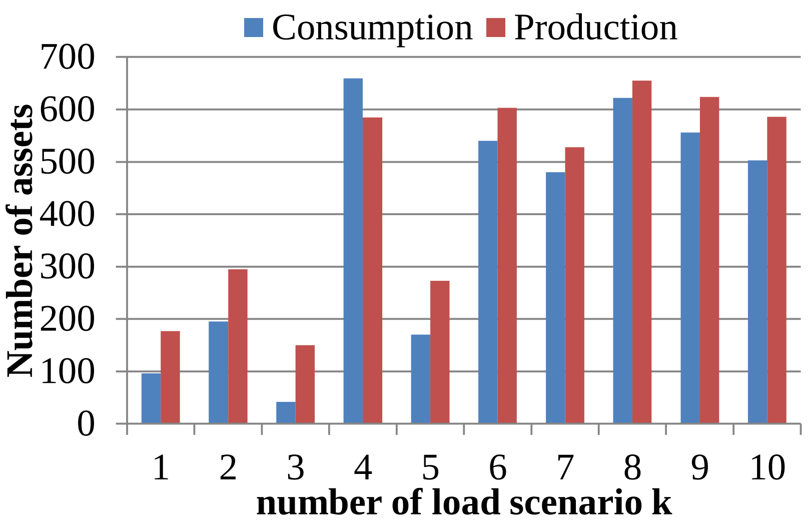
10 load scenarios		peak load scenario	
$H_{C,ACC}$ in 1/a	$H_{P,ACC}$ in 1/a	H_C in 1/a	H_P in 1/a
0.7006	0.8887	0.4804	0.5739

Results outage rates

Non-delivered & non-supplied energy of the ten load scenarios



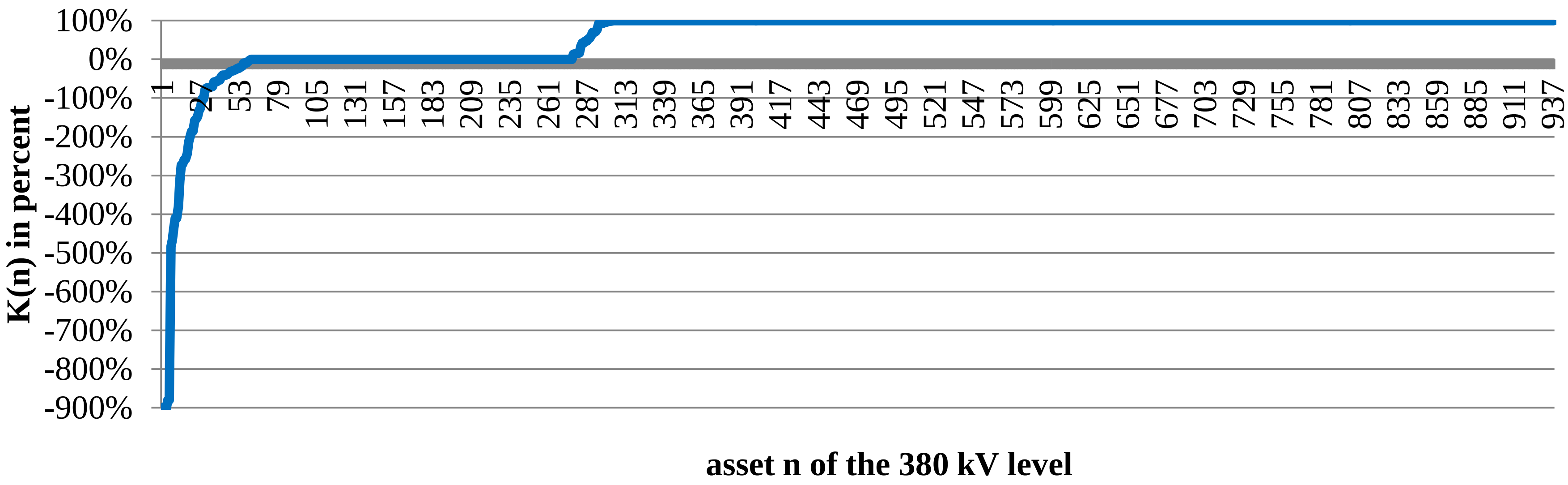
Number of assets responsible for outages



Results outage rates

$$K(n) = \frac{W_{C,TL,n} - W_{C,Peak,n}}{W_{C,TL,n}} \cdot 100\ \%$$

$W_{C,Peak,n}$	non delivered energy caused by the individual asset *n* during the Peak load with averaged outage rate in MWh.
$W_{C,TL,n}$	averaged non delivered energy caused by the individual asset *n* with age-dependent outage rate within the ten load scenarios in MWh.



Conclusions & further work

Source: abb.com

- Different load & power plant scenarios are important for asset risk determination
- Age-dependent outage rates are necessary for exact analysis
- More reliability and availability data must integrated in the database

Risk-based maintenance is a good possibility to improve the reliability and availability of the transmission system and reduce operative costs.

End

Thank you for your attention.