

Development of Generation Risk Assessment by Model- Based Techniques

23 July 2026

Pavel Krcal, Ola Bäckström, and Xuhong He



Generation Risk Assessment

We are interested in an economical aspect of operations

- How do alternatives compare with respect to the expected:
 - Power generation
 - Cost of lost production
- A probabilistic model
 - Fault trees
 - Markov processes

Model-Based Approach

Knowledge base

ModelBuilder – Platform

Solvers

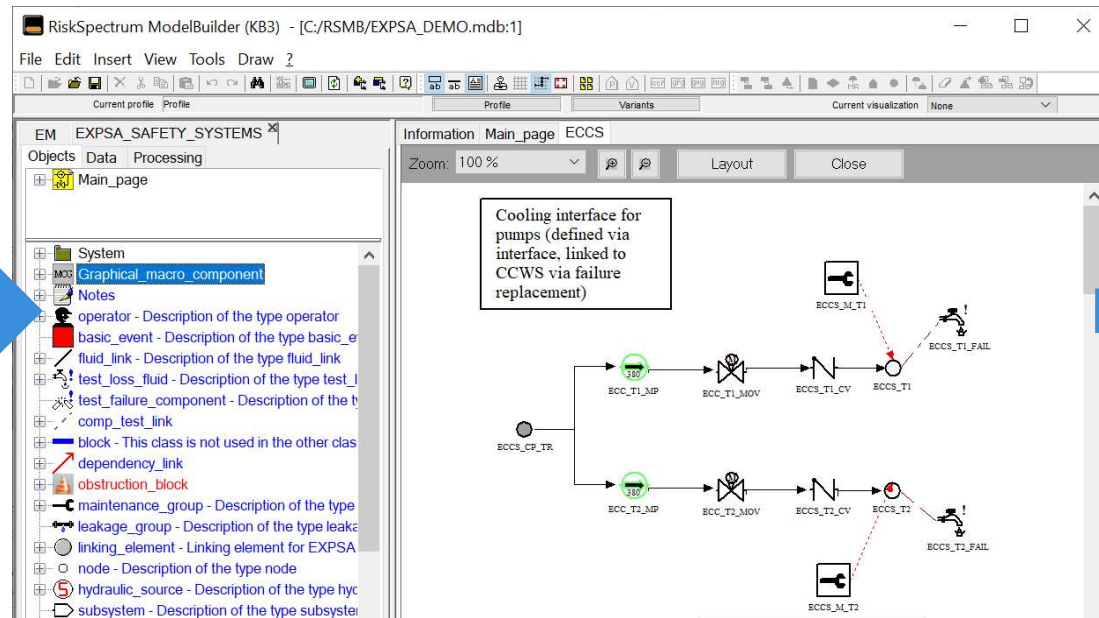
Components

Behavior including failures

Interactions

Communication

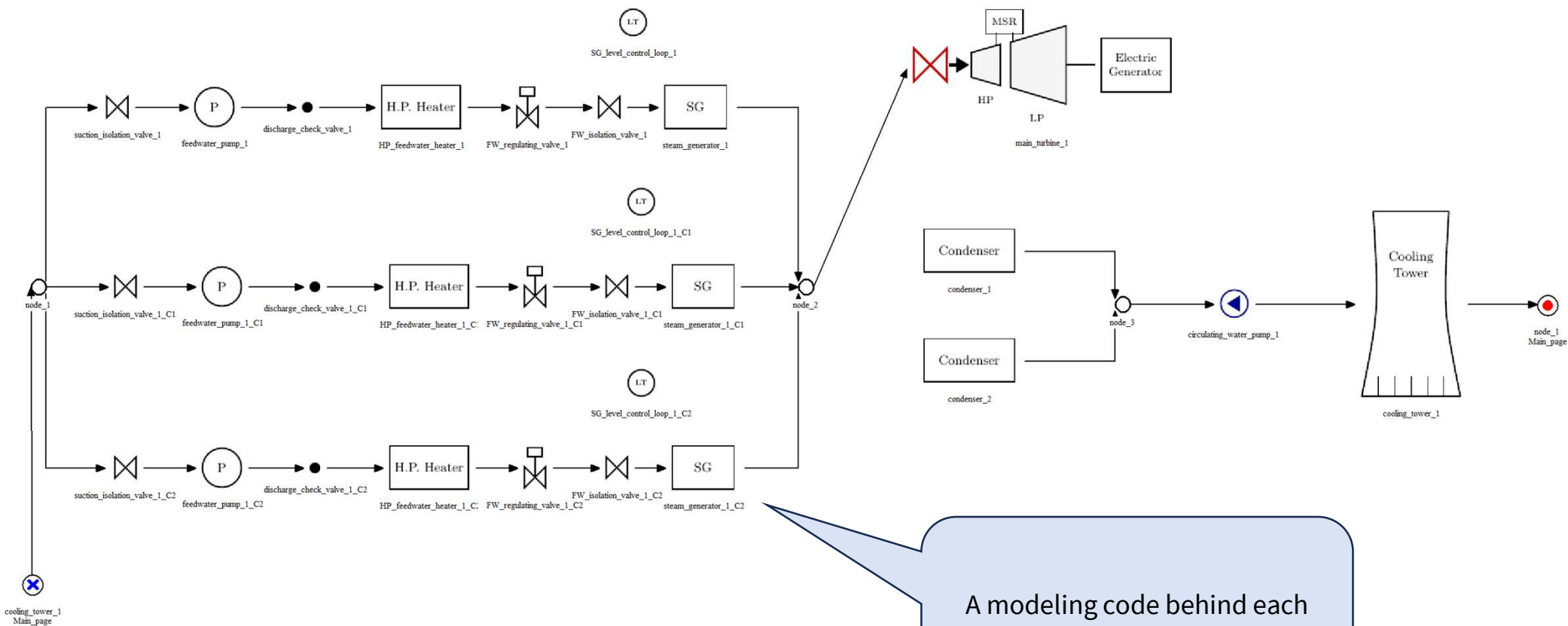
Propagation of failures



Fault trees
RS PSA

Monte Carlo
simulations

Model-Based Approach



Fault Trees

A static view



A Fault Tree-Based GRA

Fault trees generated from RSMB

- W calculations
 - Frequency (unconditional failure intensity) of different derate levels
- Time of a derate
 - Scenario dependent, sum of repair times, restoration time
- GRA value
 - Lost production in MWh or \$
 - Frequency (F), Downtime + startup time (T), Derate level (D), Production factor (P)

$$G = F \cdot T \cdot D \cdot P$$

A Fault Tree-Based GRA

Minimal cut sets and additional information

No.	W	%			Repair time	Total time	Derate	GRA (derate)	GRA (MWh)
1	4,80E-05	23,31	PUMP2_TR0024	PUMP3_TR0024	24	72	67%	2,32E-02	3,24
2	4,80E-05	23,31	PUMP1_TR0024	PUMP2_TR0024	24	72	67%	2,32E-02	3,24
3	4,80E-05	23,31	PUMP1_TR0024	PUMP3_TR0024	24	72	67%	2,32E-02	3,24
4	9,60E-06	4,66	PUMP3_TR0024	VALV1_TR0072	72	120	67%	7,72E-03	1,08
5	9,60E-06	4,66	PUMP2_TR0024	VALV1_TR0072	72	120	67%	7,72E-03	1,08

Monte Carlo Simulations

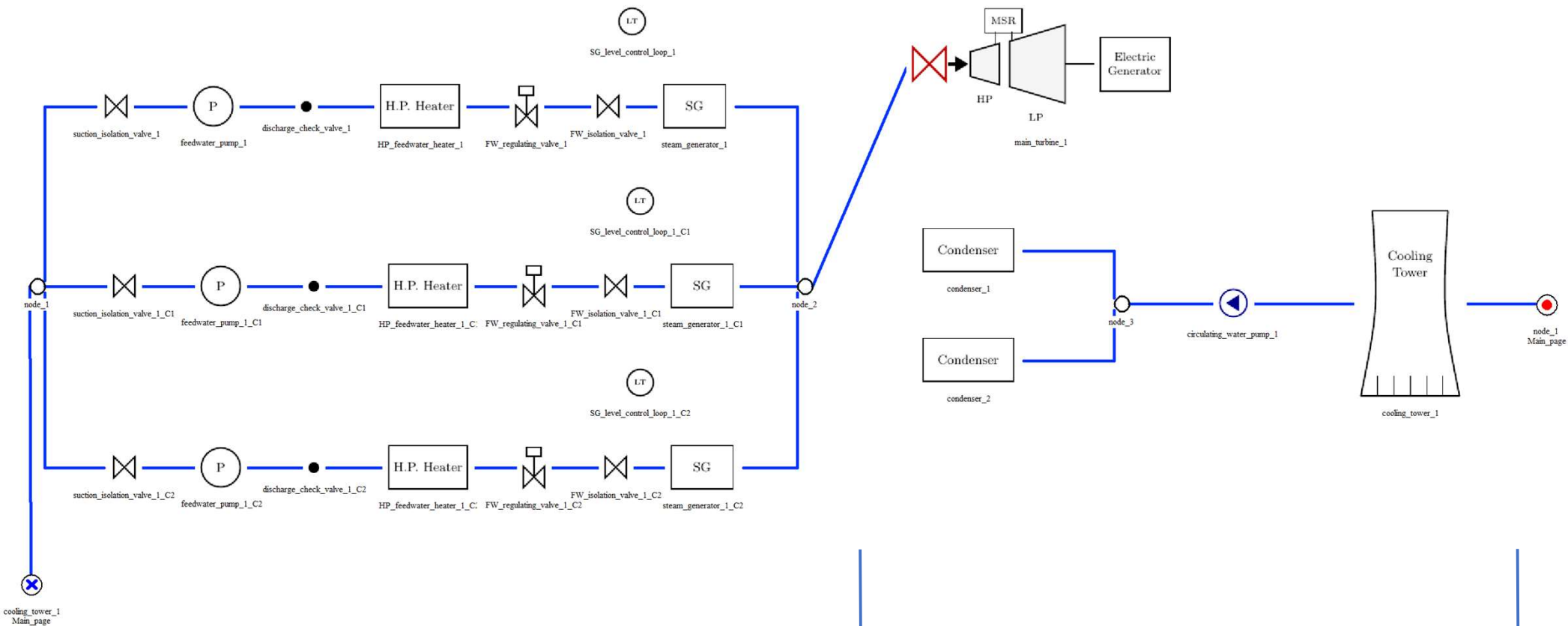
Dynamic aspects included



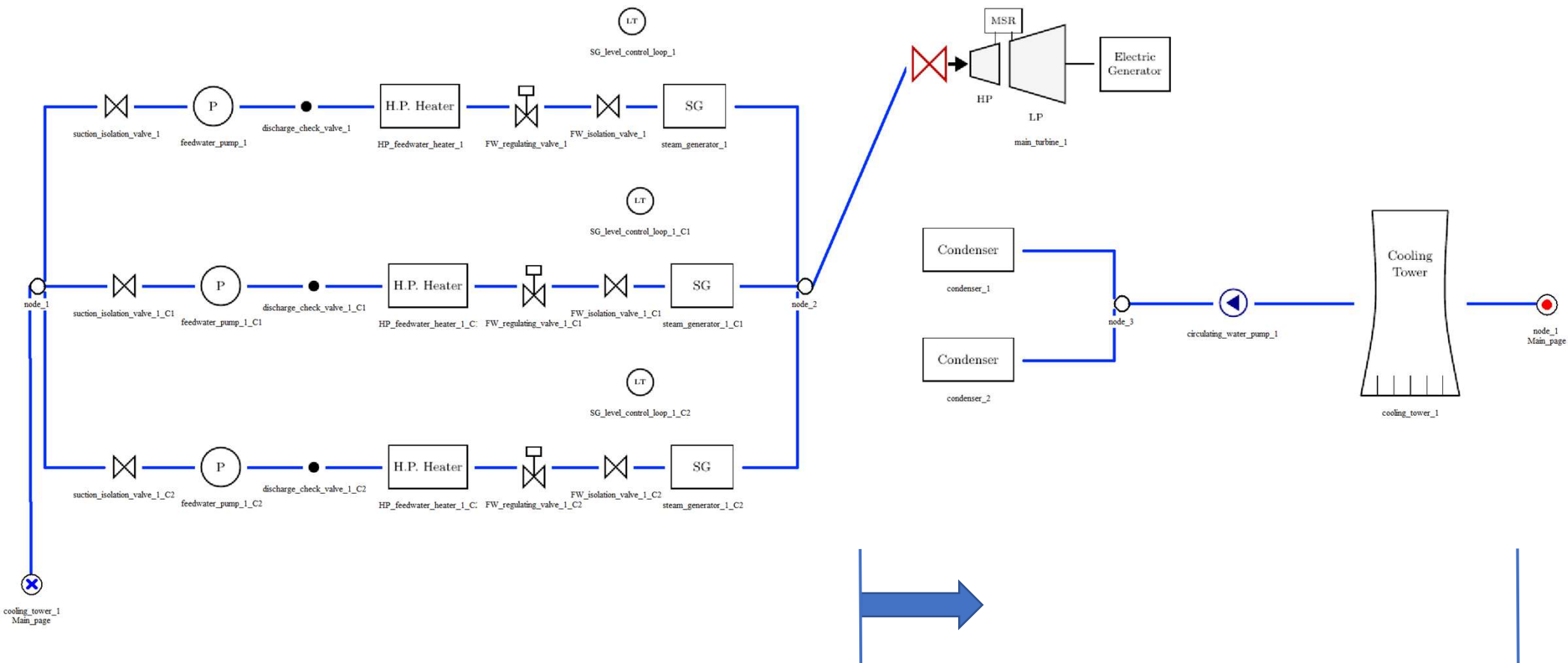
Dynamic Aspects

- The concrete scenario determines the derate and the necessary repair (time, cost)
- Reconfigurations
 - Pump 1 fails
 - Pumps 2 and 3 can serve also Train 1
 - If reconfiguration succeeds, then there is no derate
 - Otherwise, we need to repair Pump 1
- Costs can be calculated during simulations
- Results directly talk about lost power and cost of lost production

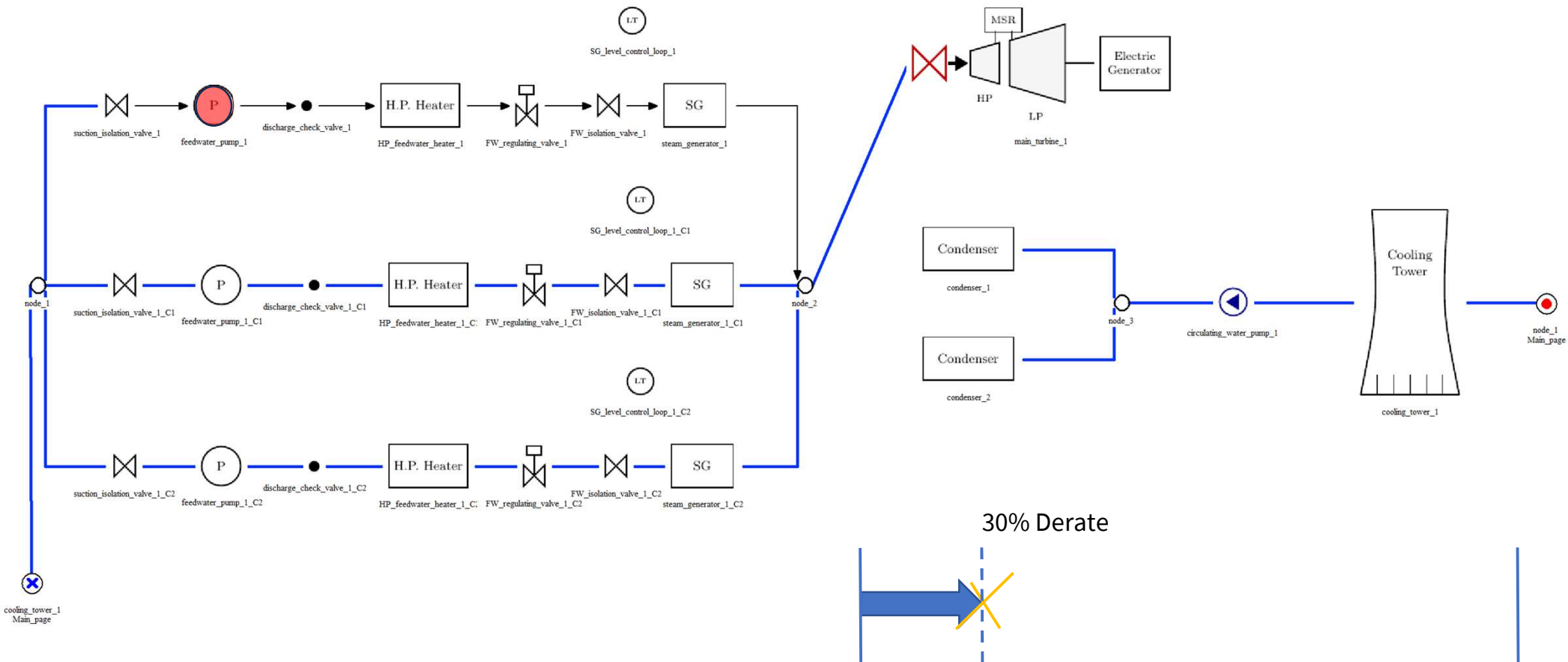
An Example of a Pump Failure



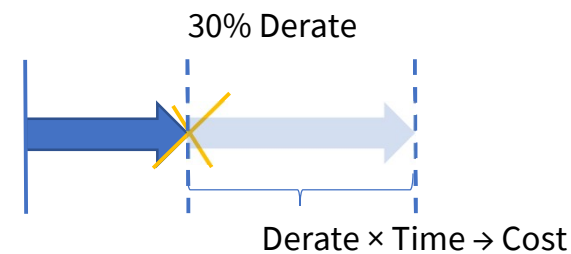
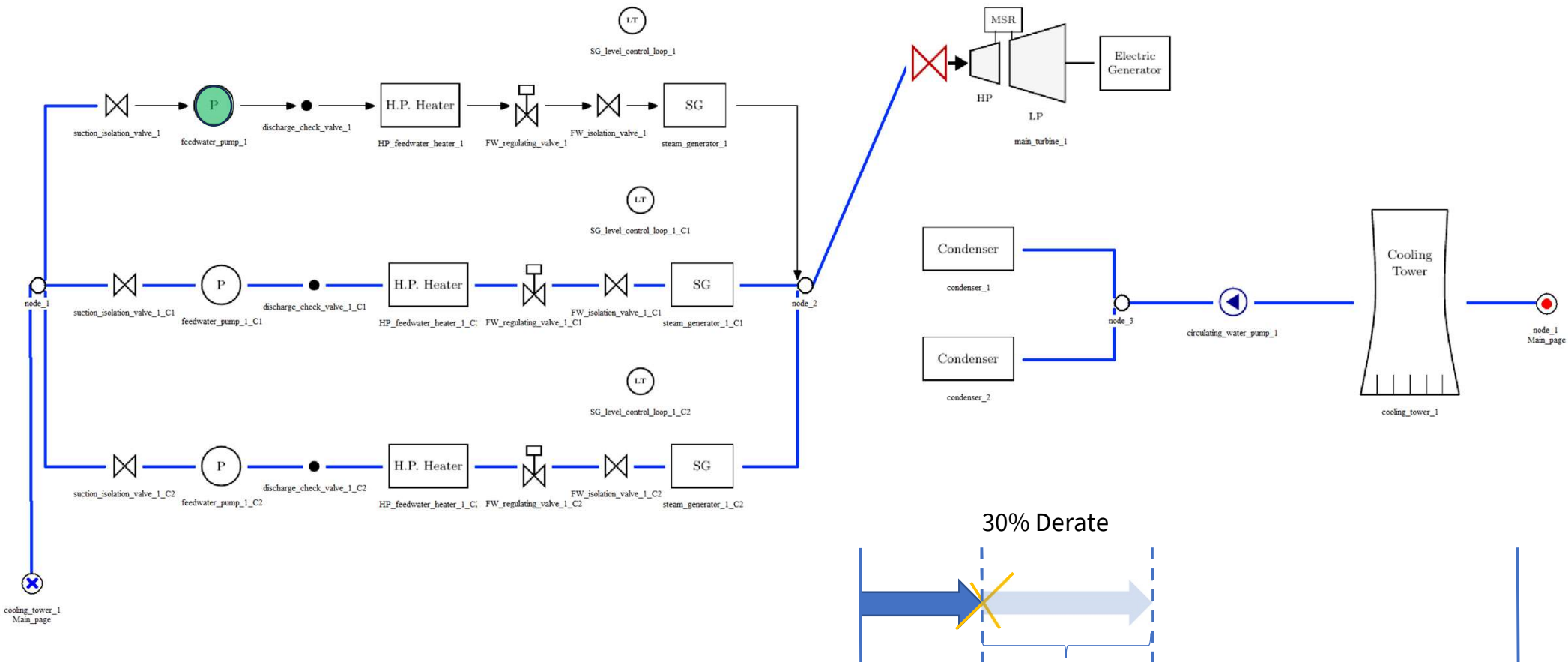
An Example of a Pump Failure



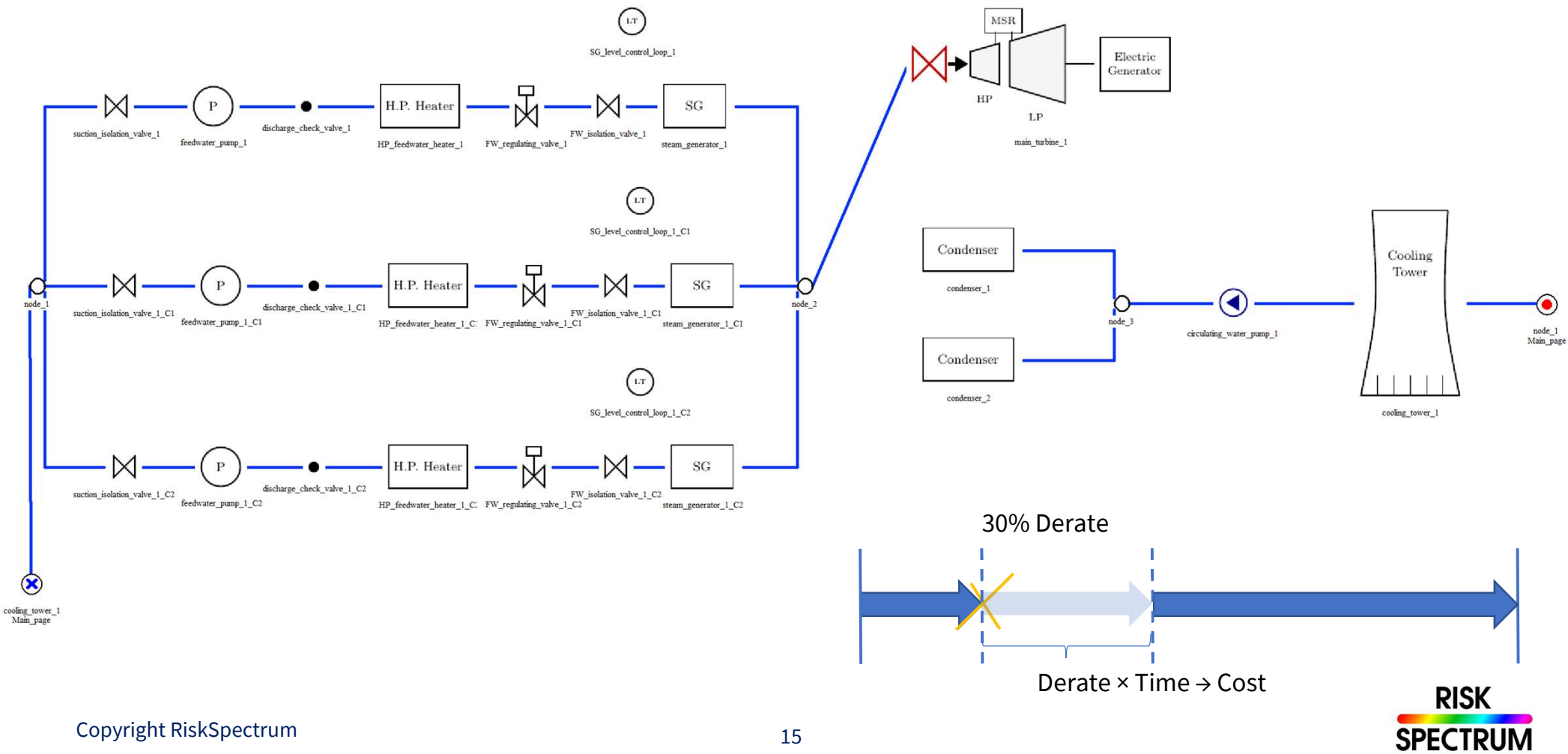
An Example of a Pump Failure



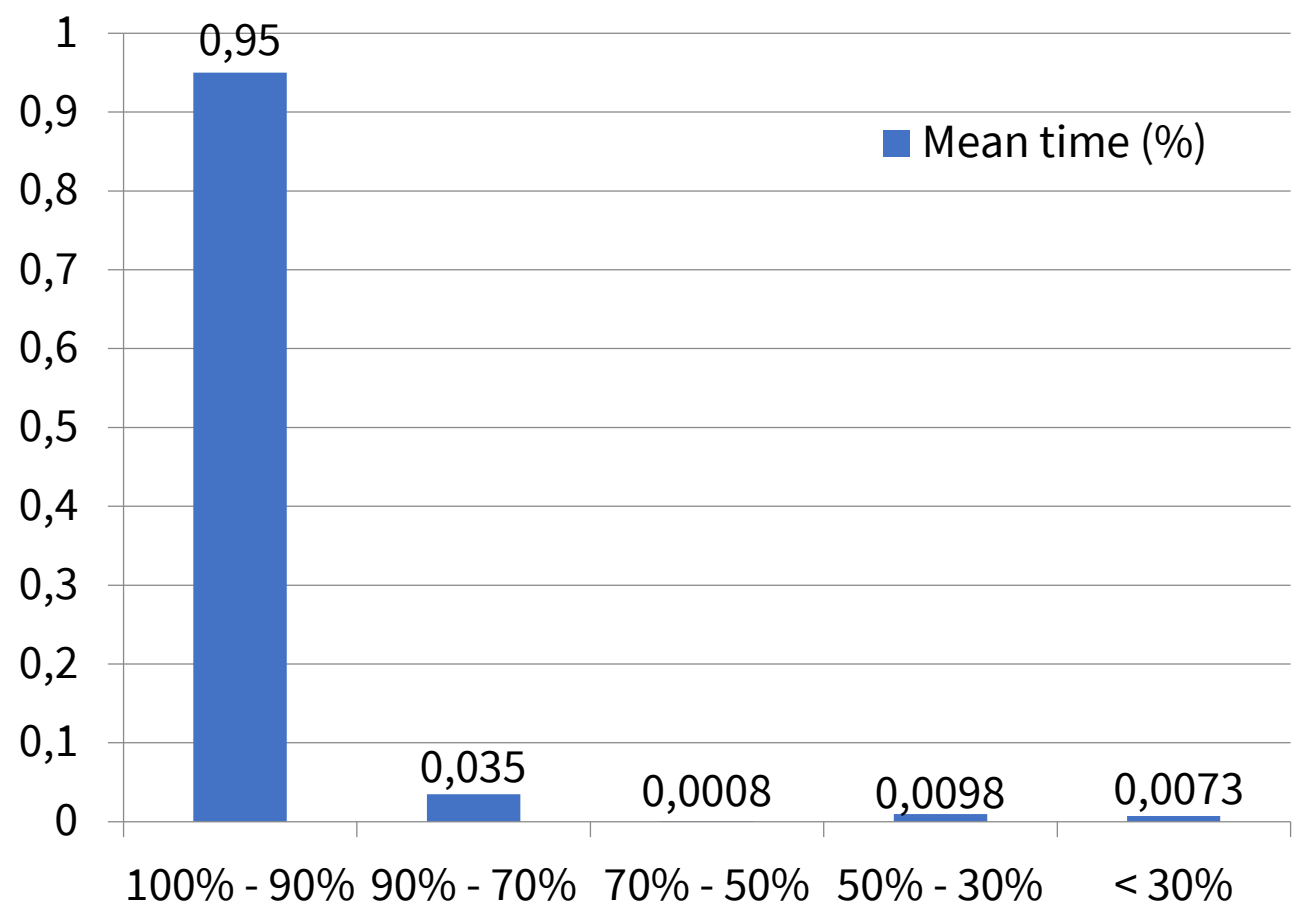
An Example of a Pump Failure



An Example of a Pump Failure



A Derate Level Distribution (Specific Conditions)



Instant	Mean production (%)
0	99.95
10000	97.5
20000	97.2
30000	97.6
40000	97.4
50000	97.1
60000	97.5
70000	97.8
80000	97.3
90000	97.4
100000	97.4

Conclusions



Conclusions

Model-based GRA

- Same model can be used for FTA and for MC simulations
- Convenient work with the model (systems engineering level)
- Powered by a knowledge base
- Fault Tree Analysis
 - Each derate level separately
 - Post-processing: repair/restore times, additional information
- Monte Carlo simulations
 - Included in the dynamic model: repairs, costs, reconfigurations, derate levels
 - Multiple probabilistic distributions



Thank you

Please contact:

support@riskspectrum.com