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Provision of Control Reserve for Wind Turbines

- Drivers for power imbalances
- Probabilistic dimensioning of control reserve
- Control reserve due to wind generation in Germany

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Introduction

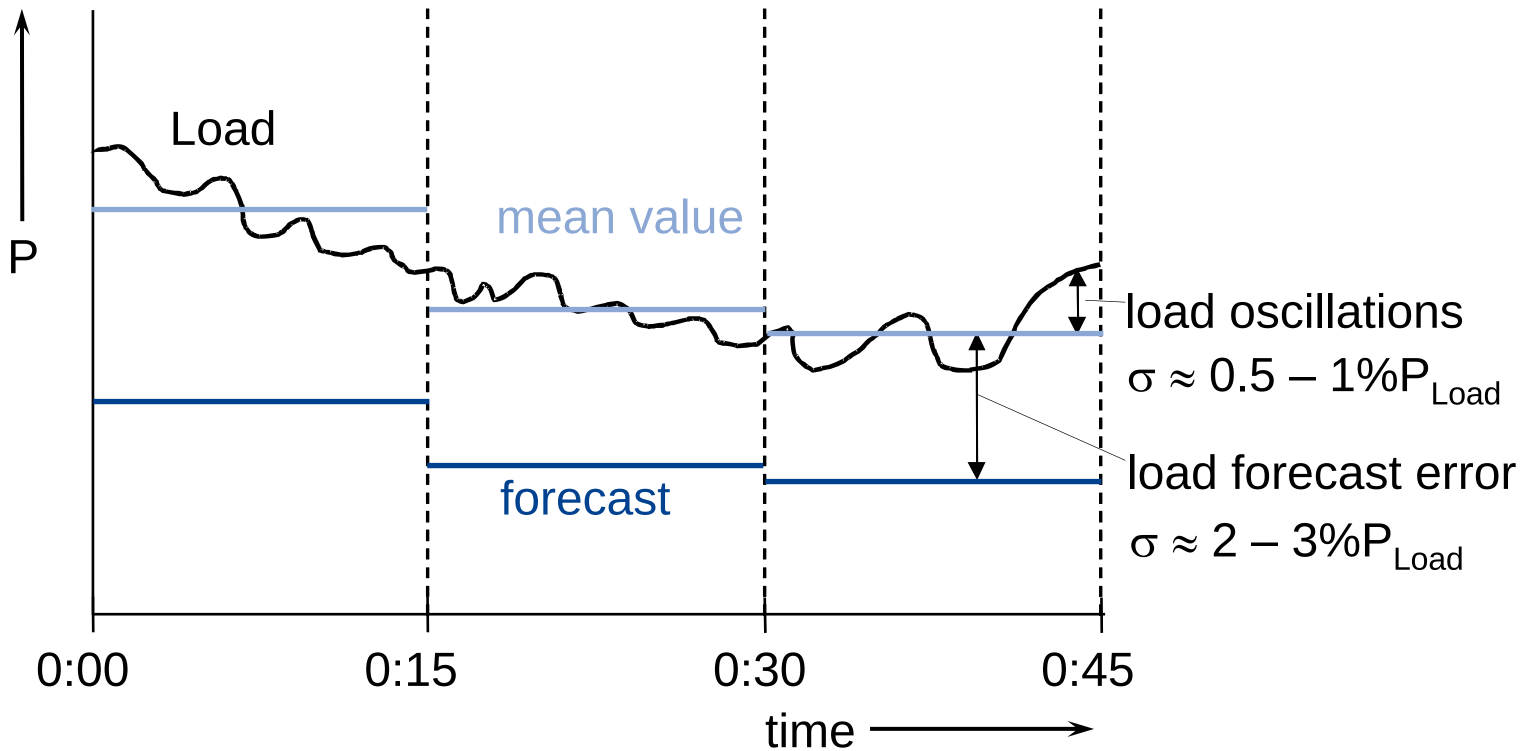
- Load frequency control has an important impact on security of supply
- Efficiency of load frequency control depends highly on available control reserve

- Rising wind generation increases the demand of control reserve significantly
- Provision of control reserve causes high costs
- → Dimensioning of control reserve requires an objective method

- Drivers for power imbalances
  - Power Plant Outages
  - Load Variations
  - Forecast Errors

1. Modelling Load Uncertainty

- Load oscillations: deviation between present actual load and 15-minutes-mean value
- Load forecast error: deviation between the forecast and 15 minutes mean value of the load



2. Power Plant Outages

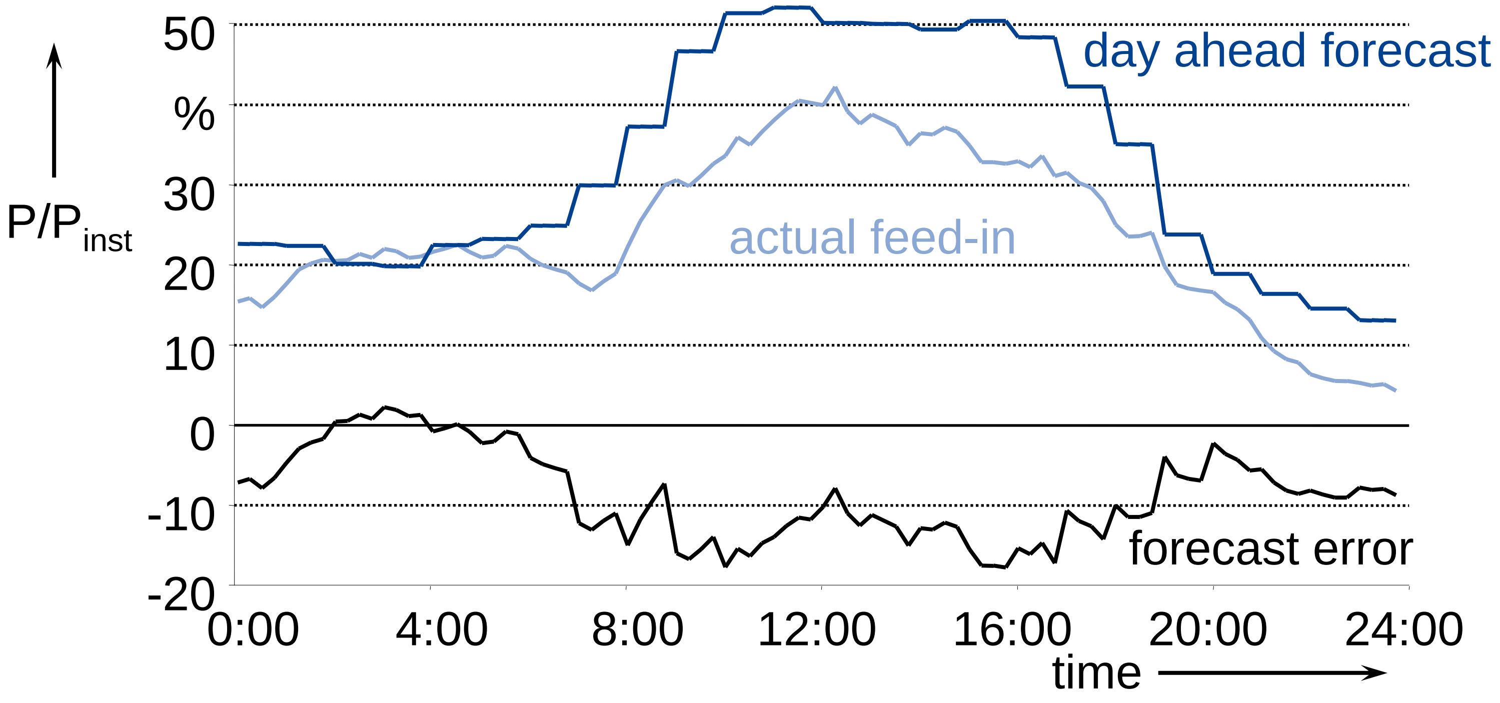
- Unplanned and not disposable outages significantly affect the demand of control reserve
- → Control demand is affected by installed capacity and outage frequency
- → Outage behaviour can be described by stochastic characteristics

Typical outage characteristics

Power Plant type	Total outage [1/a]	Partial outage [1/a]	Unit Power [MW]
nuclear	2	5	< 1500
lignite	8	9	< 1000
hard coal	7	8	< 800
gas	2	2	< 600

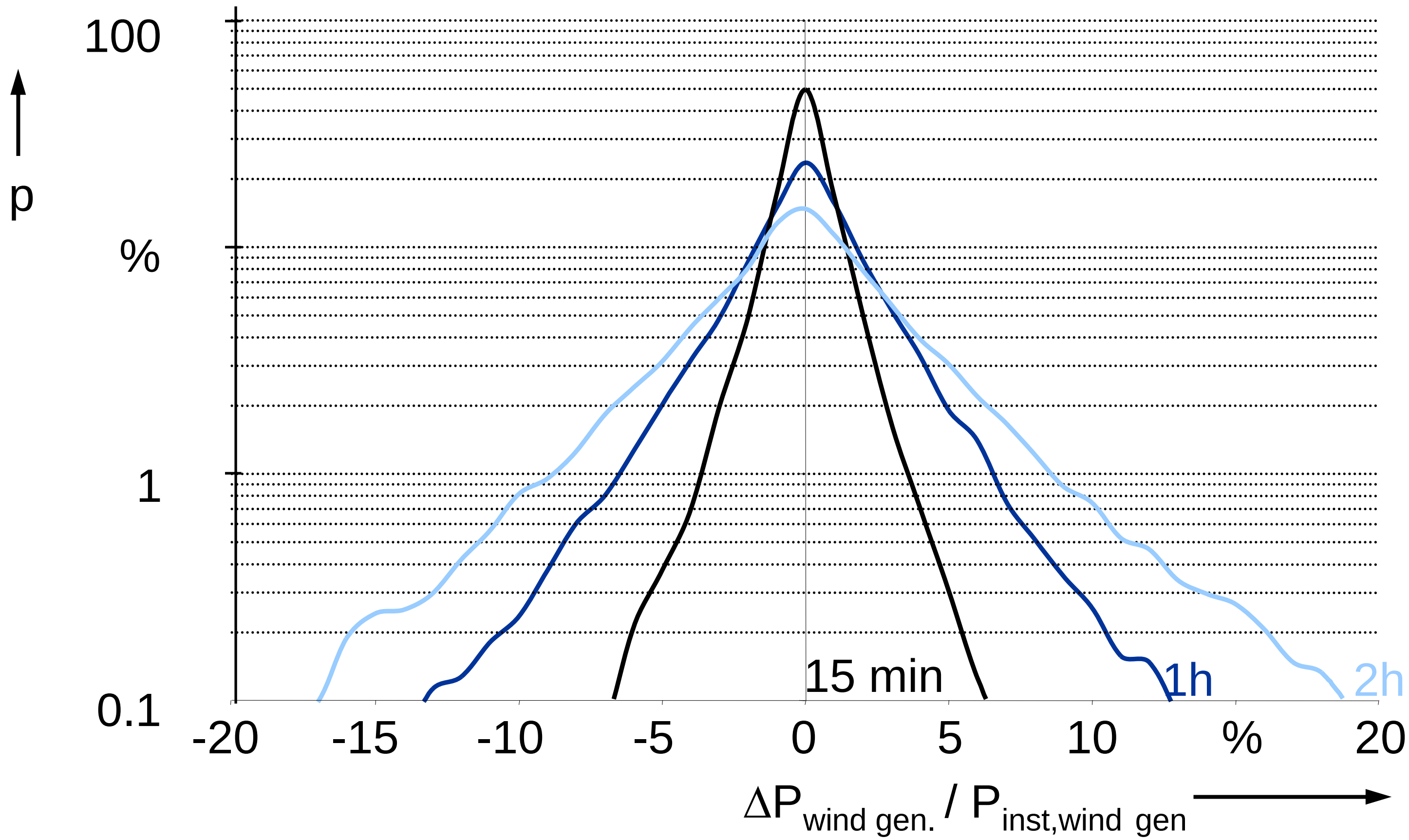
3. Wind Forecast Error

- For purposes of operational planning schedules of wind generation are required
- Generation forecasts are converted to schedules



➔ Resulting forecast error has to be compensated by control reserve

Feed-in Gradient of Wind Generation



➔ Relatively slow changes in total generation of very large groups of wind generators

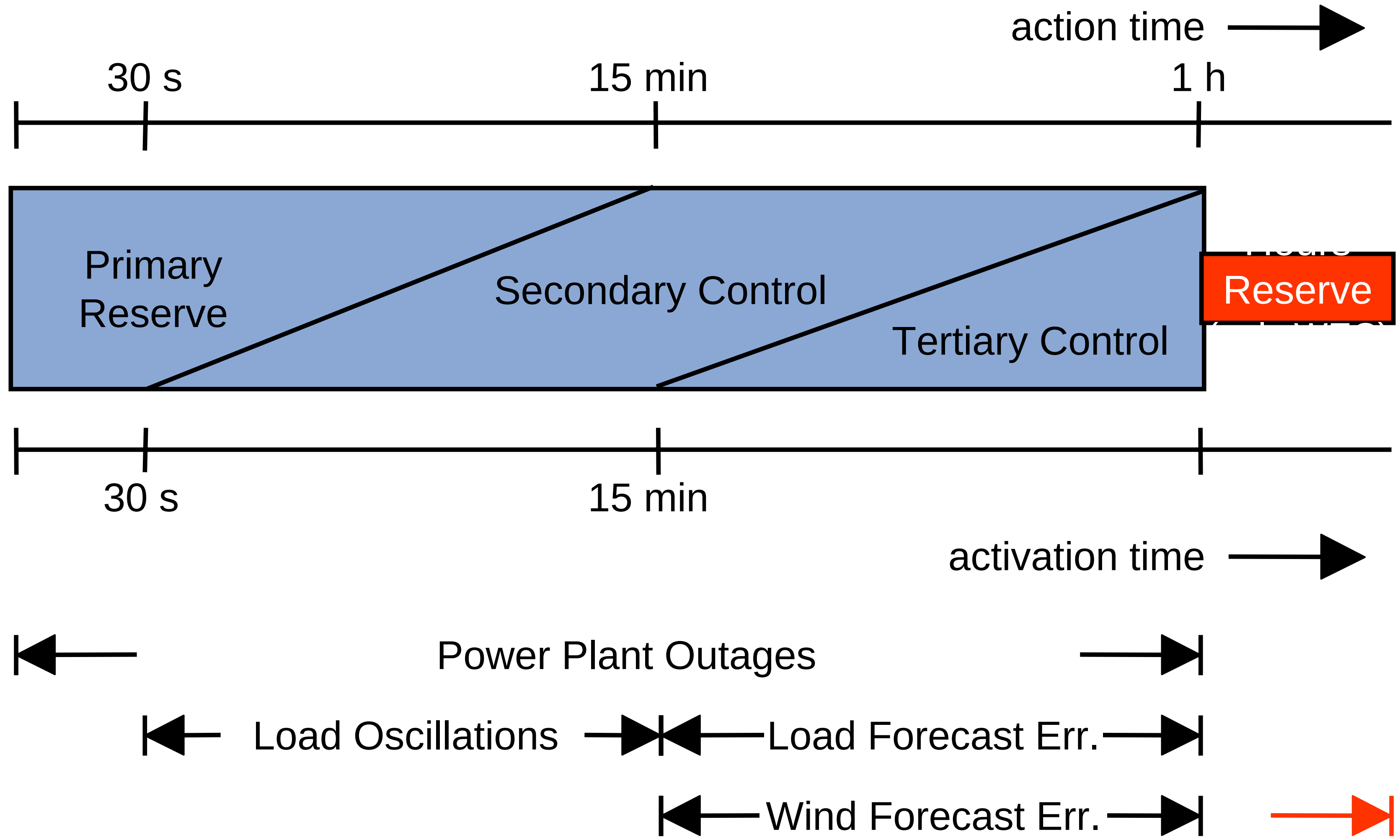
Probabilistic Criterion for Dimensioning Control Reserve

- Application of a probabilistic criterion for dimensioning of control reserve
  - Undesired system state: insufficient control reserve to cover power imbalances
  - Worst-case scenario where all drivers contribute to the power imbalance is extremely unlikely
  - → Defining maximum acceptable values for deficit and overrun probabilities

➔ Dimensioning of control reserve is based on the probability density function of power imbalances in a particular control area.

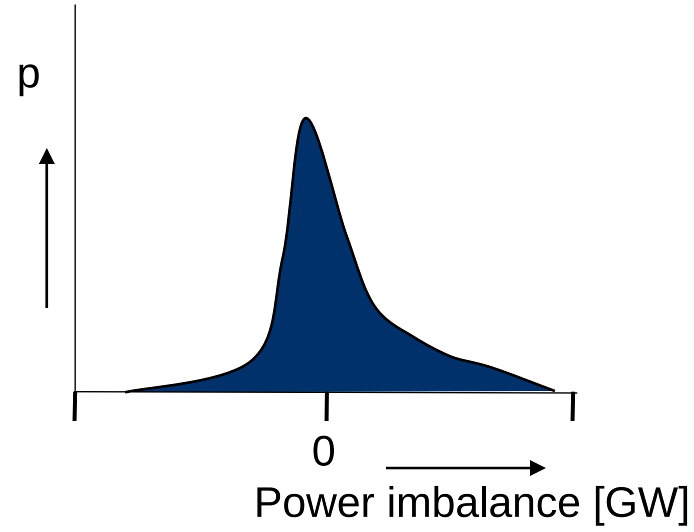
- Considering load imbalances due to
  - Load oscillations and load forecast error
  - Power Plant outages
  - Forecast error of wind generation

Allocation of Drivers to Time Domains of Load-Frequency Control



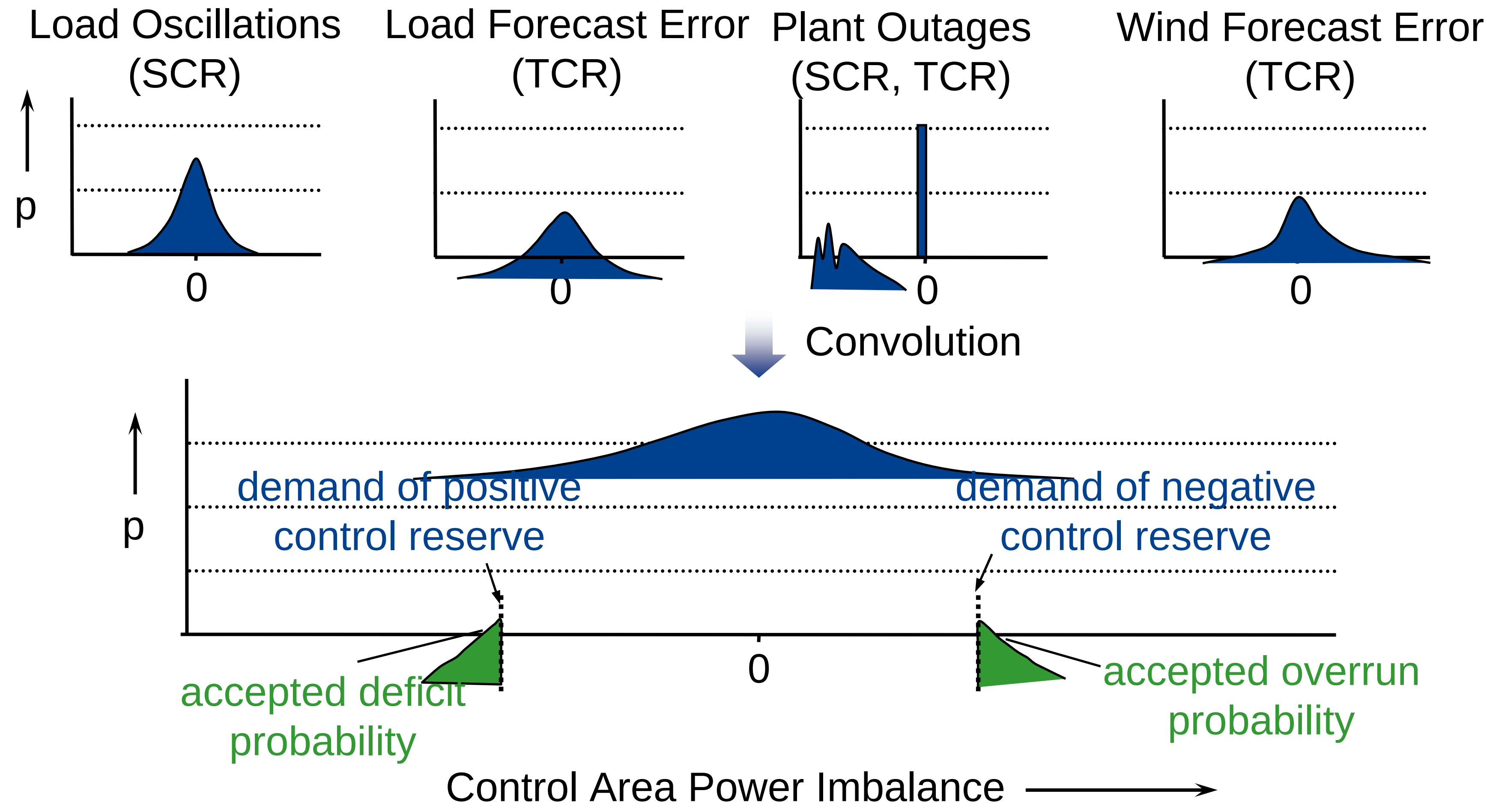
Describing the stochastic characteristic of drivers

- Power imbalance is modelled for each driver by a probability density function



- Probability density function describes the probability (time/year) for the occurrence of a particular power deviation
- Assumption: Drivers are stochastically independent

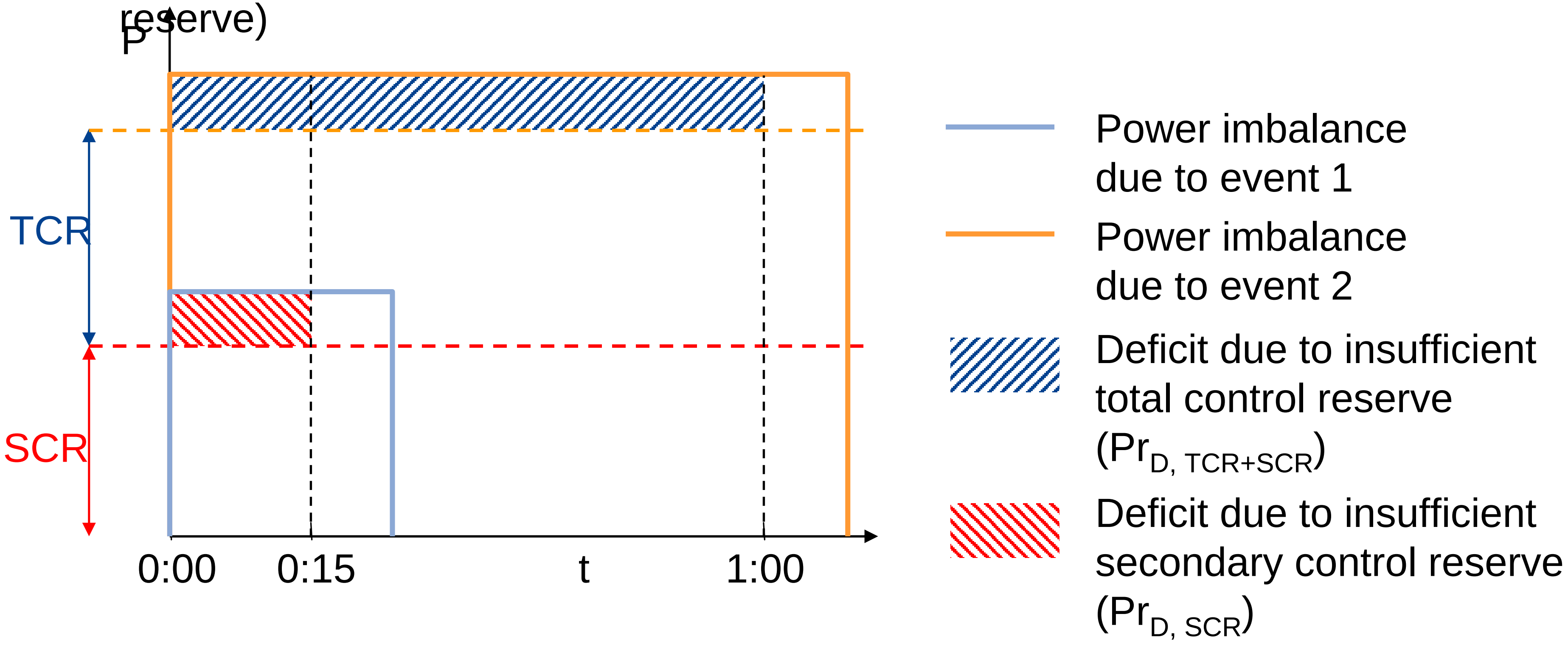
Analytic Method Based on Convolution Algorithm



Determination of Overrun and Deficit Probability

- Tertiary control reserve can be substituted by secondary control reserve at any time

➔ Considering total control reserve (sum of secondary and tertiary control reserve)



- Typical values in Germany: $Pr_{D,\ TCR+SCR} + Pr_{D,\ TCR} = 0.1\%$ (≈ 10 h/a)

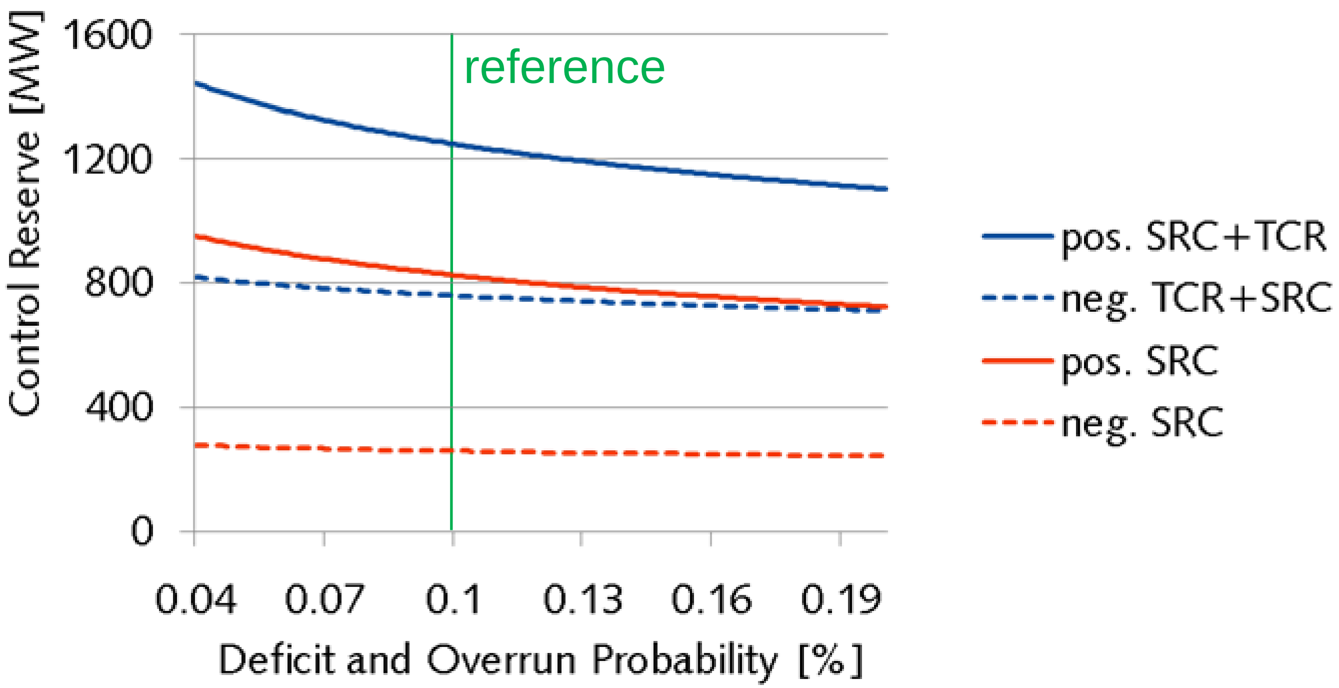
Example System

- In order to demonstrate the method and analyse the dependency of the demand of control reserve by the described drivers an example system is considered
- Considering one control block
  - Peak load: 15 GW
  - Power plant park: orientated on German generation mix
  - Load oscillations: σ = 0.5 %
  - Load forecast error: σ = 1.5 %

- The impact of the different drivers for power imbalances is analysed in sensitivity analyses
  - Accepted deficit probability
  - Load forecast error
  - Installed wind generation

Variation of Accepted Deficit Probability

- Accepted deficit and overrun probability must be specified

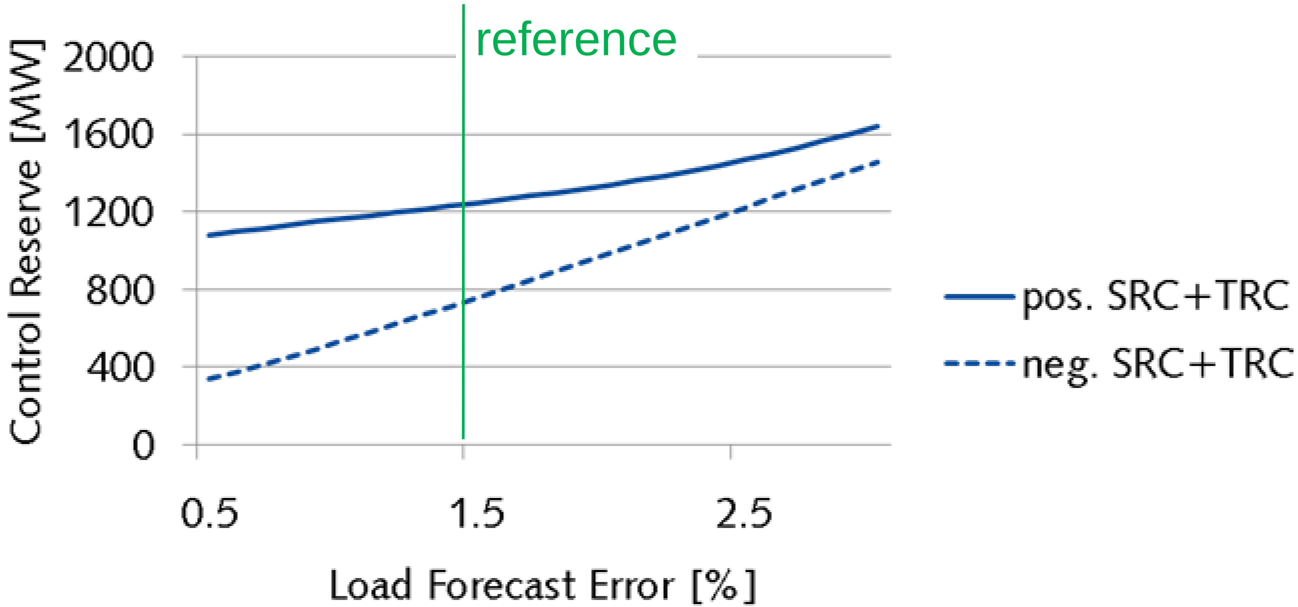


➔ Necessary control reserve significantly depends on the accepted deficit level

➔ In Germany $Pr_D = Pr_O = 0.1\%$ means a common value

Variation of Load Forecast Error

- Load forecast error is mainly affected by the behaviour of network users and their load forecast performance

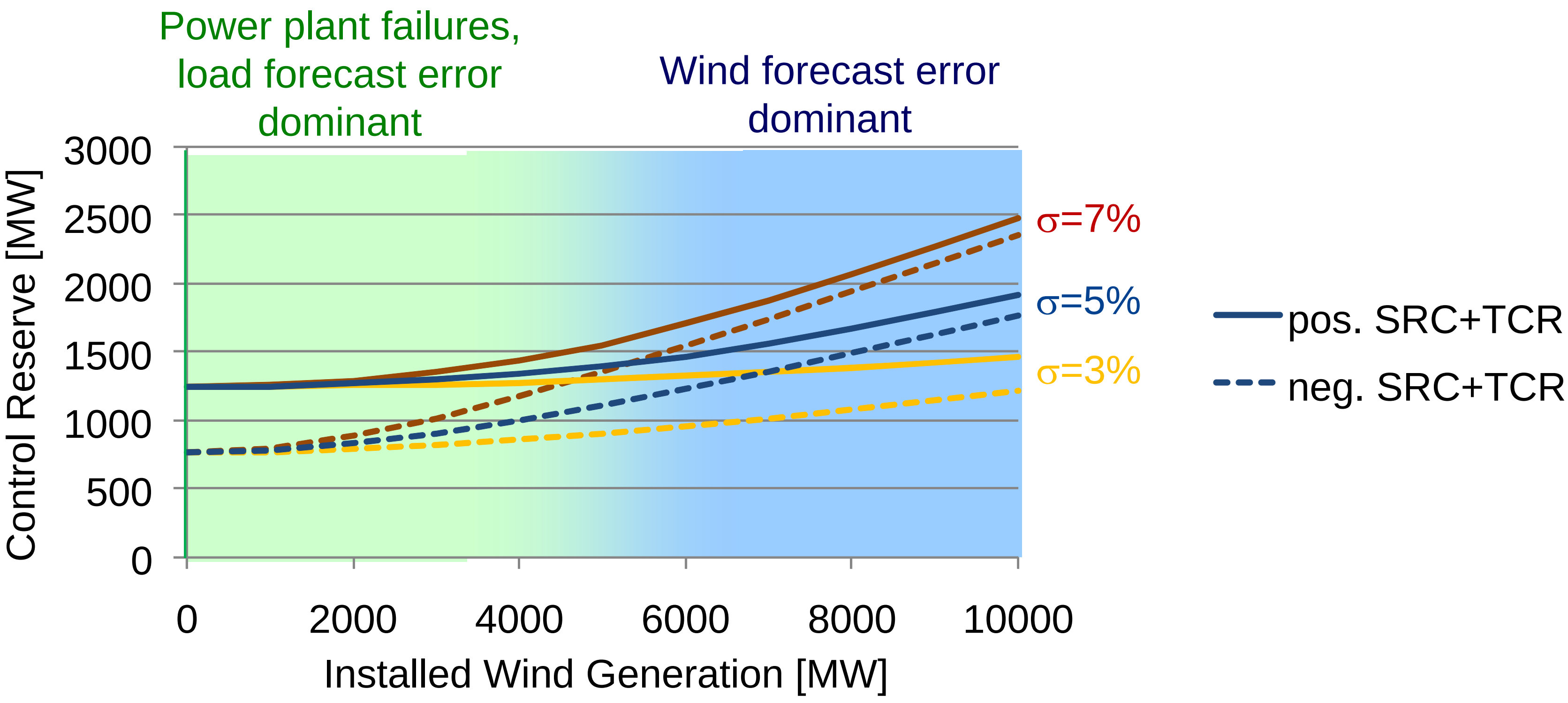


➔ Demand of TRC significantly depends on the load forecast error

➔ Impact is more significant on the negative control reserve

Variation of Wind Generation

- Variation of installed wind generation
- Forecast error assumption: σ=5%



→ Almost no effect as long the share of wind generation is low

→ Very strong effect for systems with high wind energy penetration

Conclusiones

- Rising wind generation increases the demand of control reserve significantly
- Provision of control reserve causes high costs
- ➔ Dimensioning of control reserve requires an objective method

- Important drivers for power imbalances
  - Power Plant Outages
  - Load Oscillation and Forecast Error
  - Wind Forecast Error

- Wind generation affects the necessary demand of control reserve enormously
- ➔ In systems with high penetration rate of wind generation alternative measures for reduction of control reserve demand are required