Utilizing fluctuating feed-in characteristics of WEC for grid integration

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Introduction

- Significant increase of number / installed power of wind energy converters (WEC) in electrical distribution grids (mainly MV)
- Local concentration of installed power driven by wind conditions etc.

➡ Especially in windy regions the further development of WEC-Installations is limited by available capacities for grid connection

- Conventional method: grid reinforcements driven by single grid connection request or already foreseeable grid connection projects
  - High costs and long operating lifetimes of grid components vs.
  - Future local development and especially deployment hardly predictable

  → Risk of developing long term inefficient grid structures

➡ Improved utilization of existing grid structures

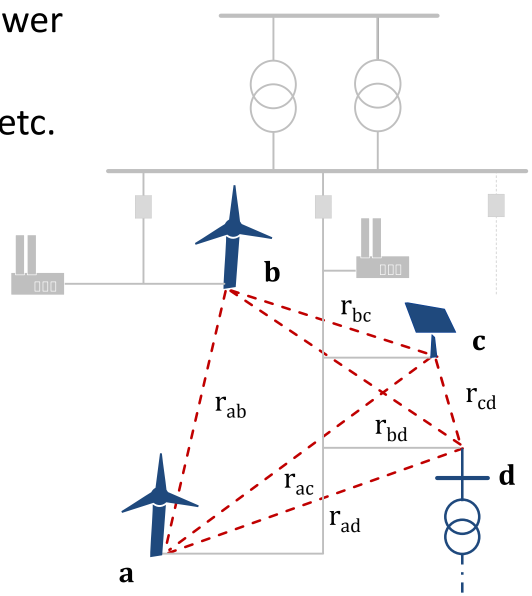
  - Flexibility
  - Cost efficiency
  - Short-term implementable solutions

Analysis

- Limiting criteria for grid connection of WEC typically given by boundaries for steady-state grid voltage and (thermal) loading of grid components
  - Limits for steady-state grid voltage acc. 50160 given for 99% of 10min.-mean-RMS-values
  - Loading capability of earth-buried cables/transformers depending on load characteristics with thermal inertia of several hours → time dependency and modelling of state transition
  - Load flows influenced by
    - Fluctuating active power feed-in of WEC and other generating plants (PV etc.)
    - Residential and industrial consumers

    → Consideration of mutual dependencies by correlation
    - Controlled reactive power provision of WEC/PV
    - Tab-position of OLTCs etc.

➡ **Time-dependent probabilistic approach with discrete time steps of 10-15min. and thermal models for state transition**



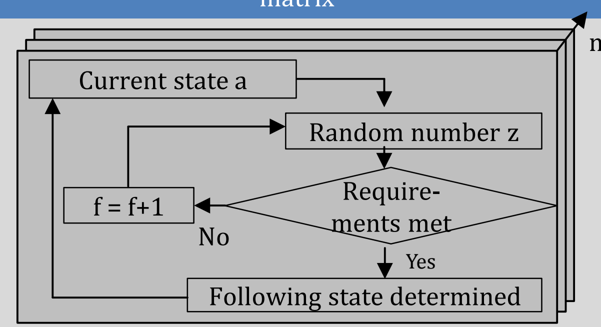
Determination of the distance matrix(Coefficients r_{ij})

Determination of the correlation matrix

$$R = \begin{pmatrix} 1 & \rho_{ab} & \rho_{ac} & \rho_{ad} \\ \rho_{ba} & 1 & \rho_{bc} & \rho_{bd} \\ \rho_{ca} & \rho_{cb} & 1 & \rho_{cd} \\ \rho_{da} & \rho_{db} & \rho_{dc} & 1 \end{pmatrix}$$

Generation of random numbers with correlation R

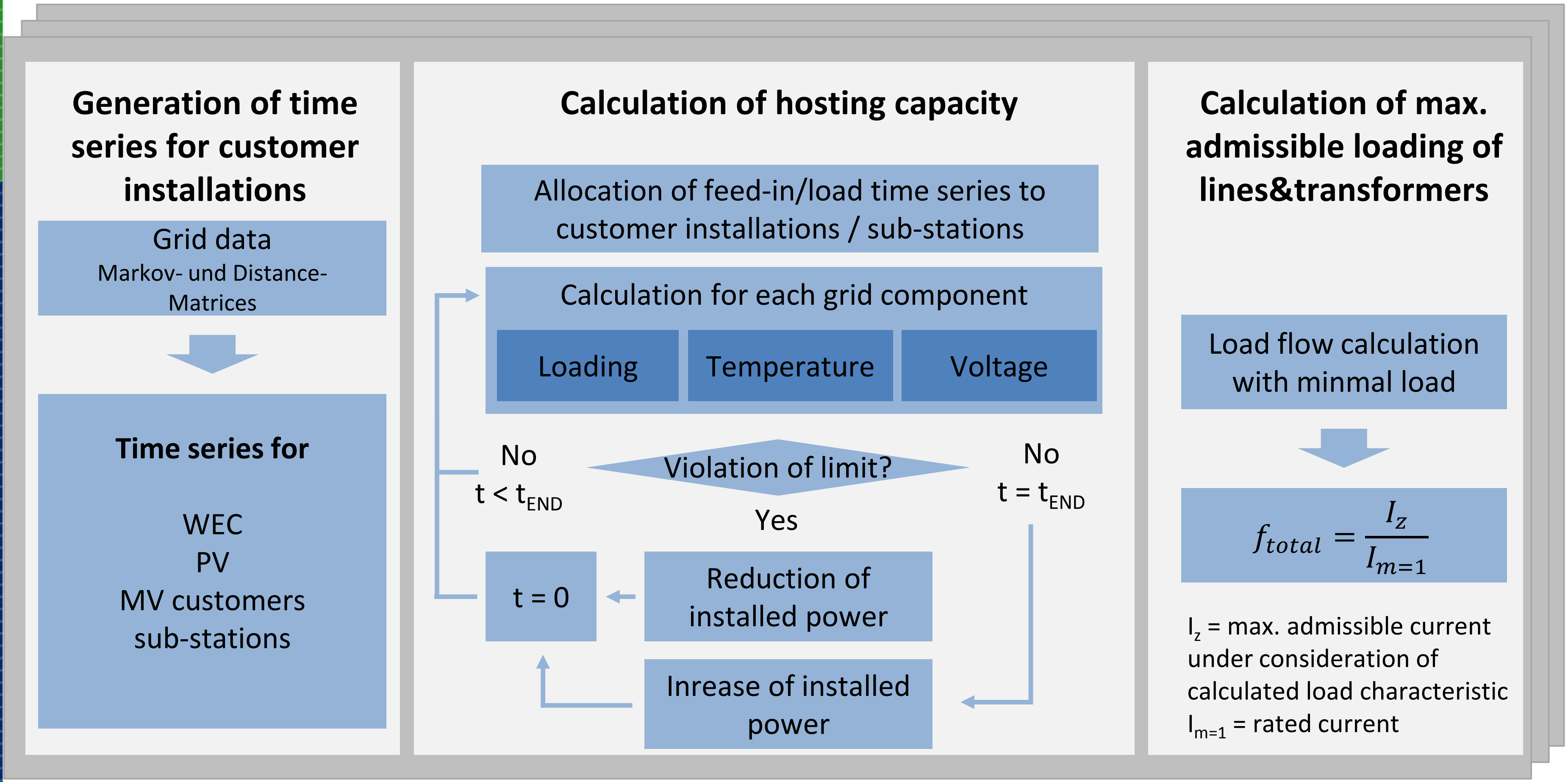
Determination of following state with state transition matrix



Analysis

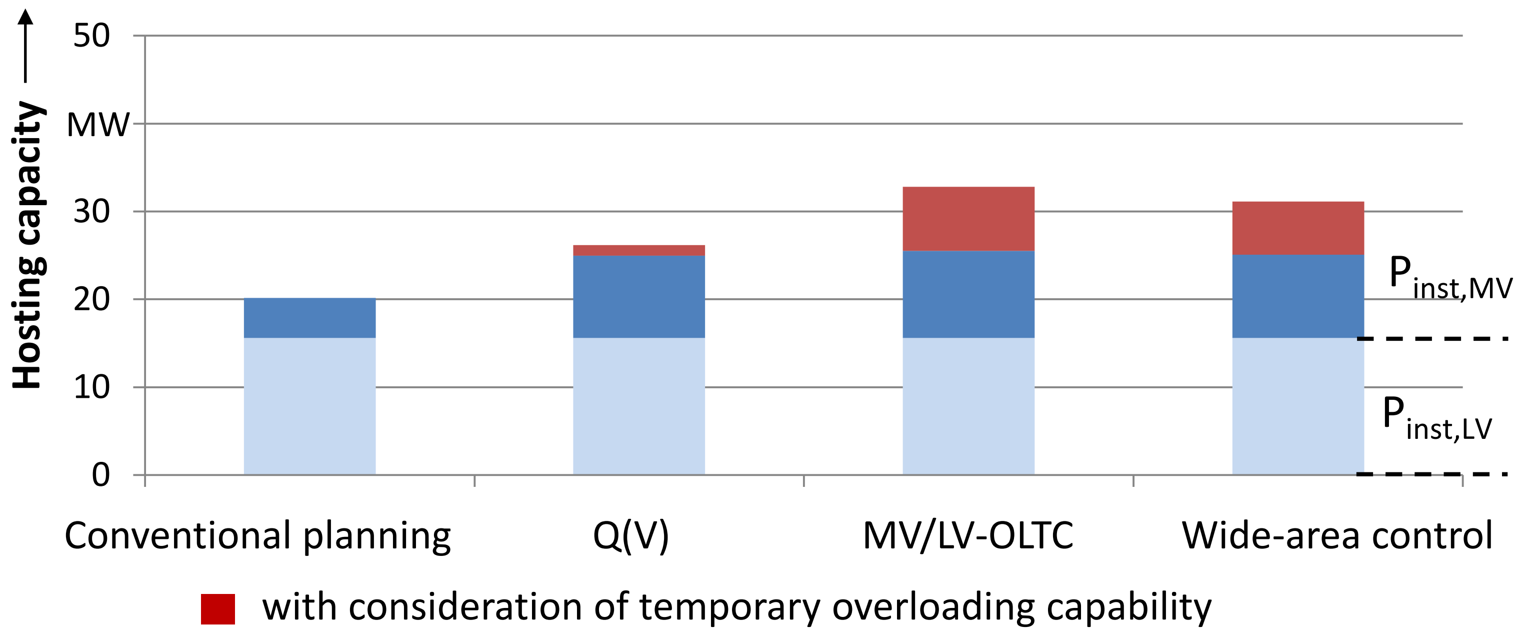
- Grid integration methods considered
  - Improved utilization of existing options for grid operation
    - Improved control concepts for transformers with OLTC
      - Wide-area-control (voltage regulation at distant network nodes)
      - Load flow dependent voltage set-point
    - Extension of range and optimised control of reactive power provision by WEC
    - Improved utilization of loading capability reserves of grid components given by thermal inertia especially of earth buried lines and transformers
  - Introduction of additional options for grid operation by actively controlled (variable) components
    - Use of MV / LV transformers with OLTC

Methodology



Exemplary results

Total hosting capacity for WEC / PV in an exemplary rural MV-grid



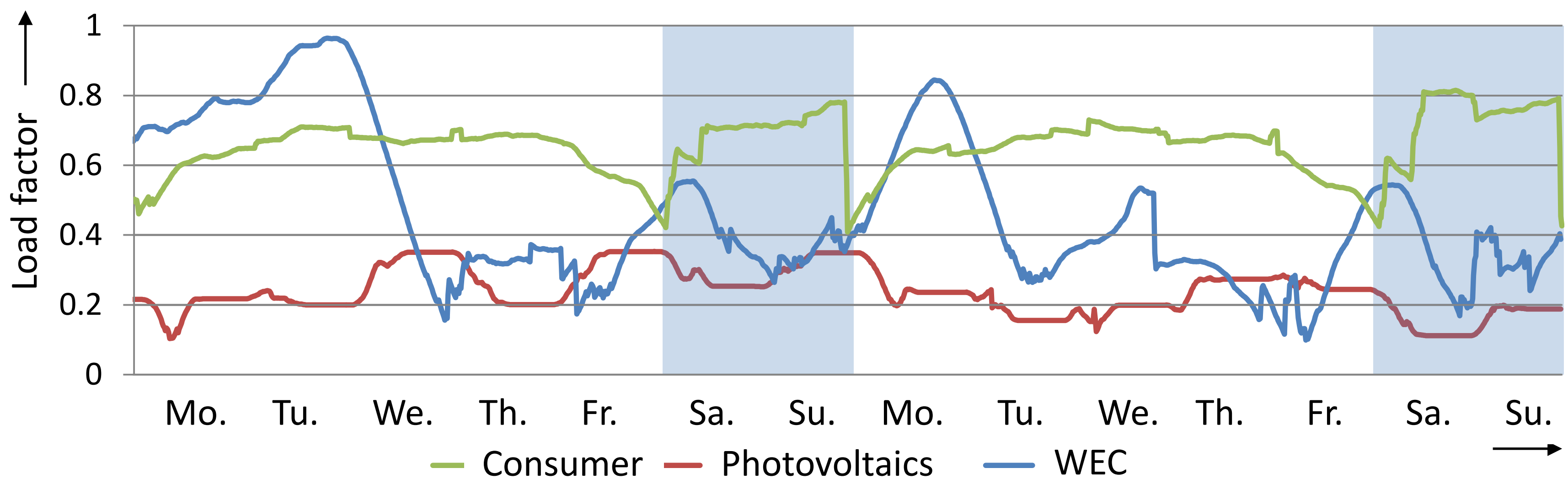
- Typical extended rural grid
  → Initially hosting capacity limited by steady-state voltage boundaries

➡ Innovative voltage regulation strategies improve HC until limits of loading capability are reached (if voltage issues are entirely resolved)

➡ Consideration of temporary overload capabilities enables further increase of HC without any additional costs

Load factor under consideration of volatile load characteristics

- Conventional daily cyclic loading characteristic only valid for conventional distribution networks without significant share of WEC / PV
- Fluctuating feed-in characteristics of wind turbines and photovoltaic systems lead to deviating load profiles



➡ Conventionally defined load factor not appropriate when assessing the real loading capacity of grid components as earth-buried lines / transformers

- Solution: Determination of the maximum permissible loading, taking into account thermal inertia of (earth-buried) lines and transformers

Summary

- Especially in windy regions the further development of WEC-Installations is limited by available capacities for grid connection
- Conventional grid reinforcements are cost-intensive, cause significant project delays and may lead to long term inefficient grid structures even if embedded in an appropriate long term planning scheme

➡ Improved utilization of existing network structures using the fluctuating feed-in characteristics of WECs

  - Improved transformer control concepts
  - Temporary overloading capabilities of earth-buried cables and transformers
  - Extension of range and optimized control of reactive power provision by WEC
  - MV / LV transformers with OLTC

- Limiting criteria for grid connection of WEC typically given by boundaries for static grid voltage and (thermal) loading of grid components

➡ Time-dependent probabilistic approach with discrete time steps of 10-15min. and thermal models for state transition

- Results
  - Conventional load factor not appropriate for assessing loading capability of grid components in distribution grids with a significant share of WEC / PV
  - Innovative voltage control concepts and consideration of temporary overloading capabilities allow significantly increased hosting capacity in a wide variety of distribution grids

Thank you for your attention!

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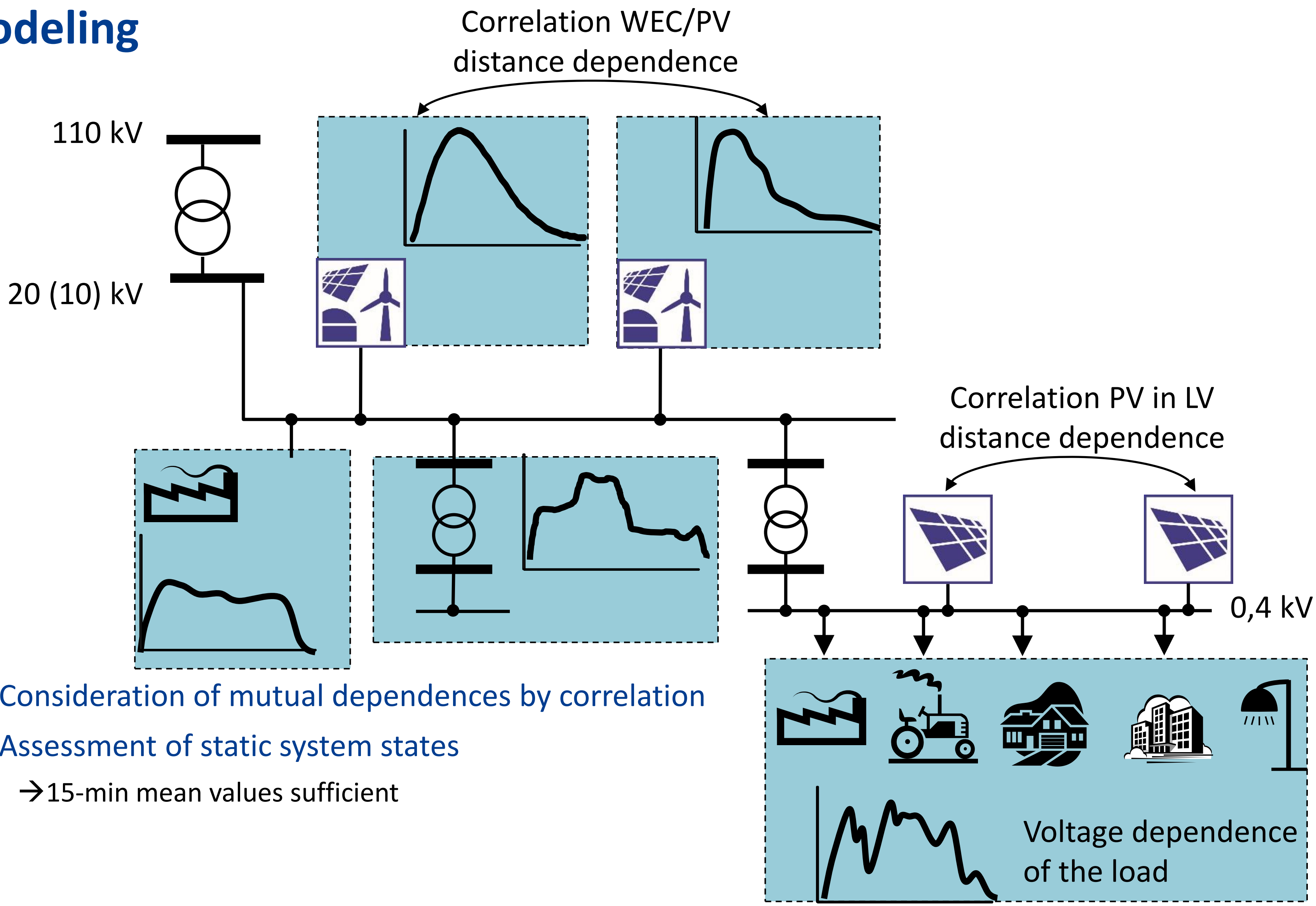
■BACKUP

Modeling



- Consideration of mutual dependences by correlation
- Assessment of static system states
  - →15-min mean values sufficient

Specific criteria for the assessment of grid connection of WEC

- Thermal current carrying capacity
  - Assessment of grid capacity for continuous load (load factor = 1)
- Static voltage limits (according to EN 50160)
  - Limits for grid voltage at the point of common coupling of customer installations
  - Assessment based on statistical criteria
- Short-circuit current
  - Grid coupling via converters: short-circuit current contribution of WEC rather small

  → Simple countermeasures: short-circuit-current-limiters
- Grid disturbances
  - Fast (switching) changes in voltage / flicker
  - Harmonics / interharmonics / ripple-control

  → Use of filters / modification of inverter frequency and/or inverter control

➡ Limiting criteria for grid connection of WEC typically given by limits for static grid voltage and thermal loading of grid components

- Aa
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