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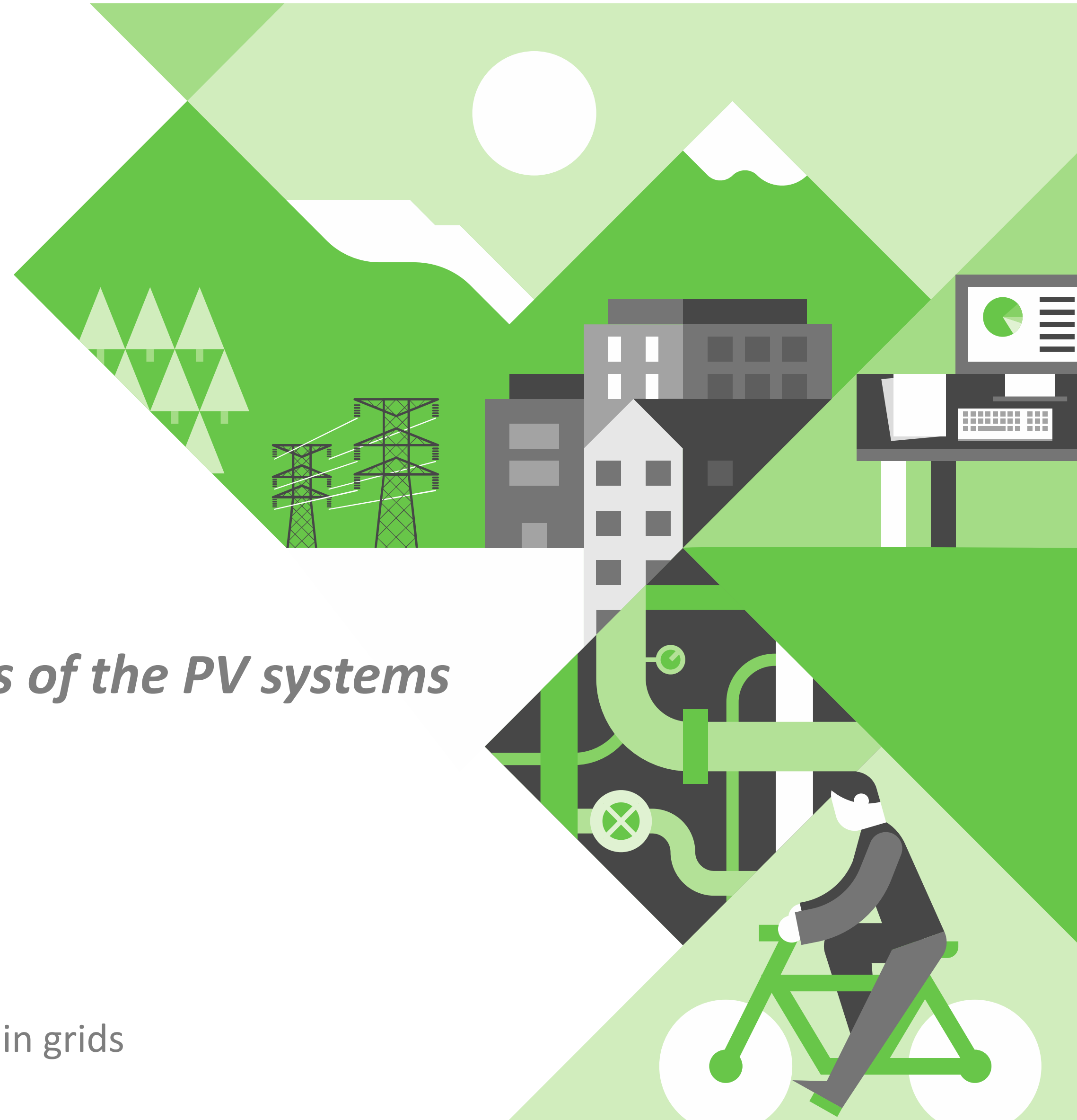

Assessment and countermeasures of the PV systems integration in distribution grids

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PARLPV - March 14, 2022 – PV in grids

Outline

- Introduction
- Hosting capacity
- PV hosting capacity evaluation: a quantitative results
- Mitigation techniques for PV integration
    - Optimal PV placement
    - Optimal battery placement
    - Smart EV charging
- Conclusions

European Photovoltaic generation target

- 2030

55% GHG reduction

40% RES use target

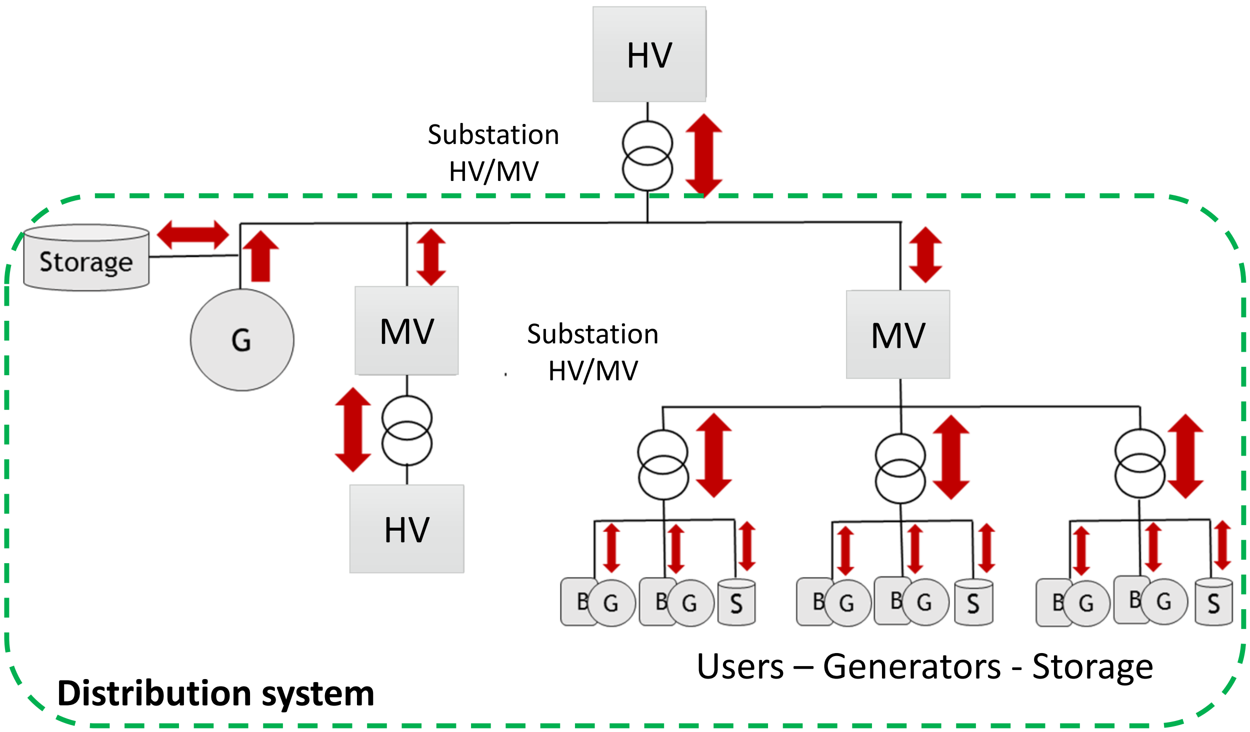
~870 GW of Solar across EU

In 2021 around **25.9 GW** of new solar PV capacity installed to the grid with an increase of **35%** with respect to 2020

- Availability of sufficient grid hosting capacity, mainly at the distribution grid can limit the solar deployment
- Important investment to mitigate the risk in the power network
- Adoption of **smart technologies** and use of **flexibility**

*Solar Power Europe

Electricity systems evolution with DERs



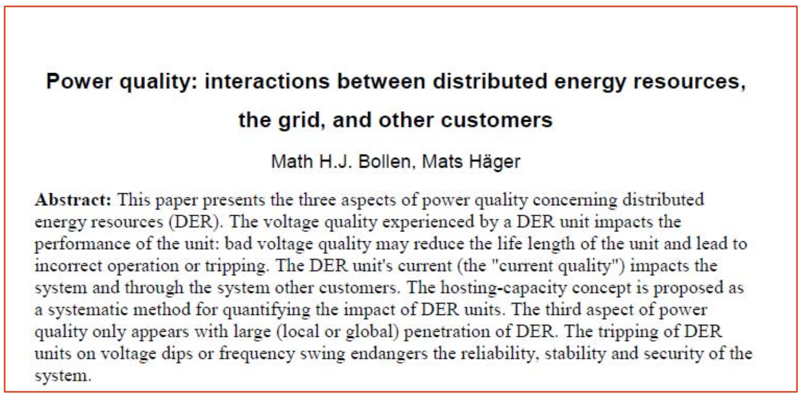
- From hierarchical to meshed system
- From monodirectional to bidirectional power flows

What is the amount of DER that can be included in the network?

Hosting Capacity

Definition: *"the amount of DER that can be integrated into a given distribution network keeping its performance within an acceptable range and without modification of the existing power grid infrastructure"*

- Hosting capacity (HC) has been introduced in 2005



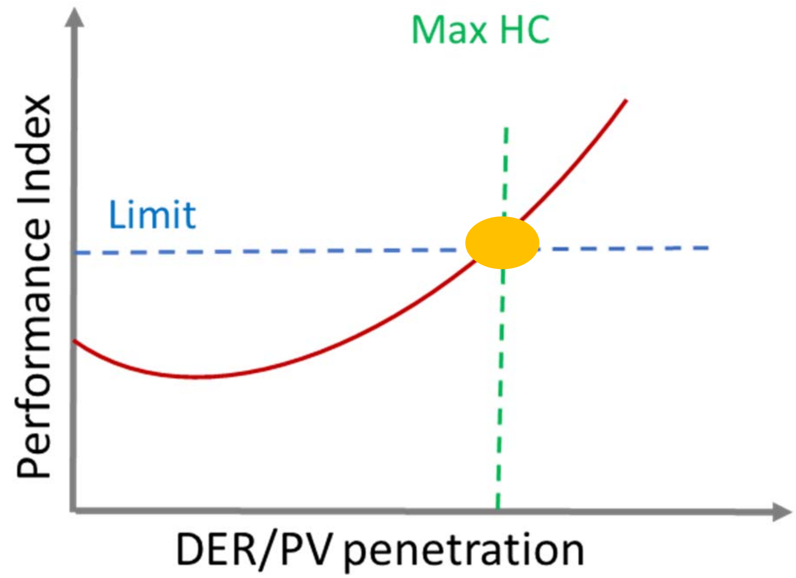
Power quality: interactions between distributed energy resources, the grid, and other customers

Math H.J. Bollen, Mats Häger

Abstract: This paper presents the three aspects of power quality concerning distributed energy resources (DER). The voltage quality experienced by a DER unit impacts the performance of the unit: bad voltage quality may reduce the life length of the unit and lead to incorrect operation or tripping. The DER unit's current (the "current quality") impacts the system and through the system other customers. The hosting-capacity concept is proposed as a systematic method for quantifying the impact of DER units. The third aspect of power quality only appears with large (local or global) penetration of DER. The tripping of DER units on voltage dips or frequency swing endangers the reliability, stability and security of the system.

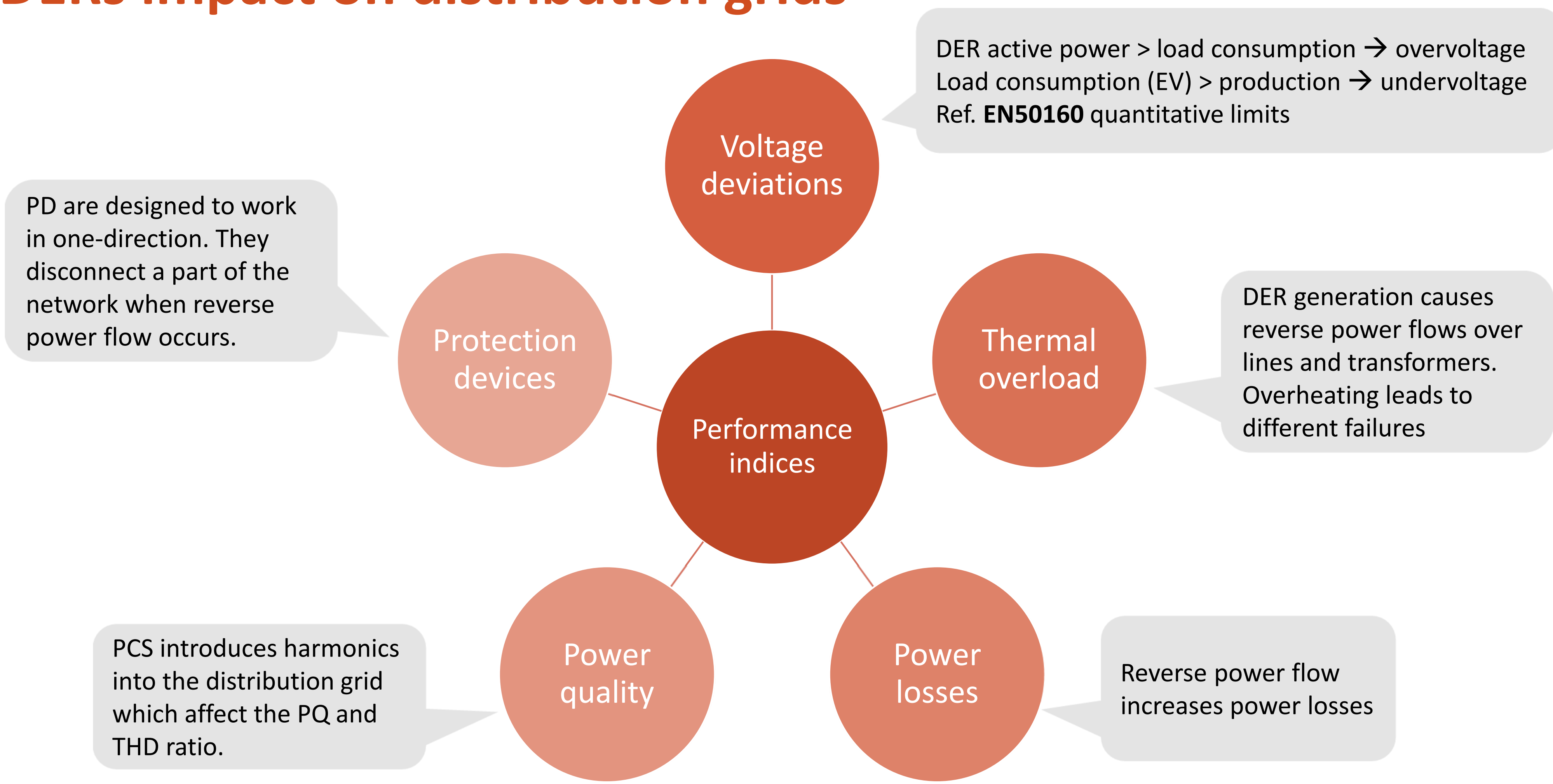
- Interest for DSO and end-customer

- Survey 2017 revealed 54% of DSO expect to reach its HC in the next 10 years → Possibly closer!!!

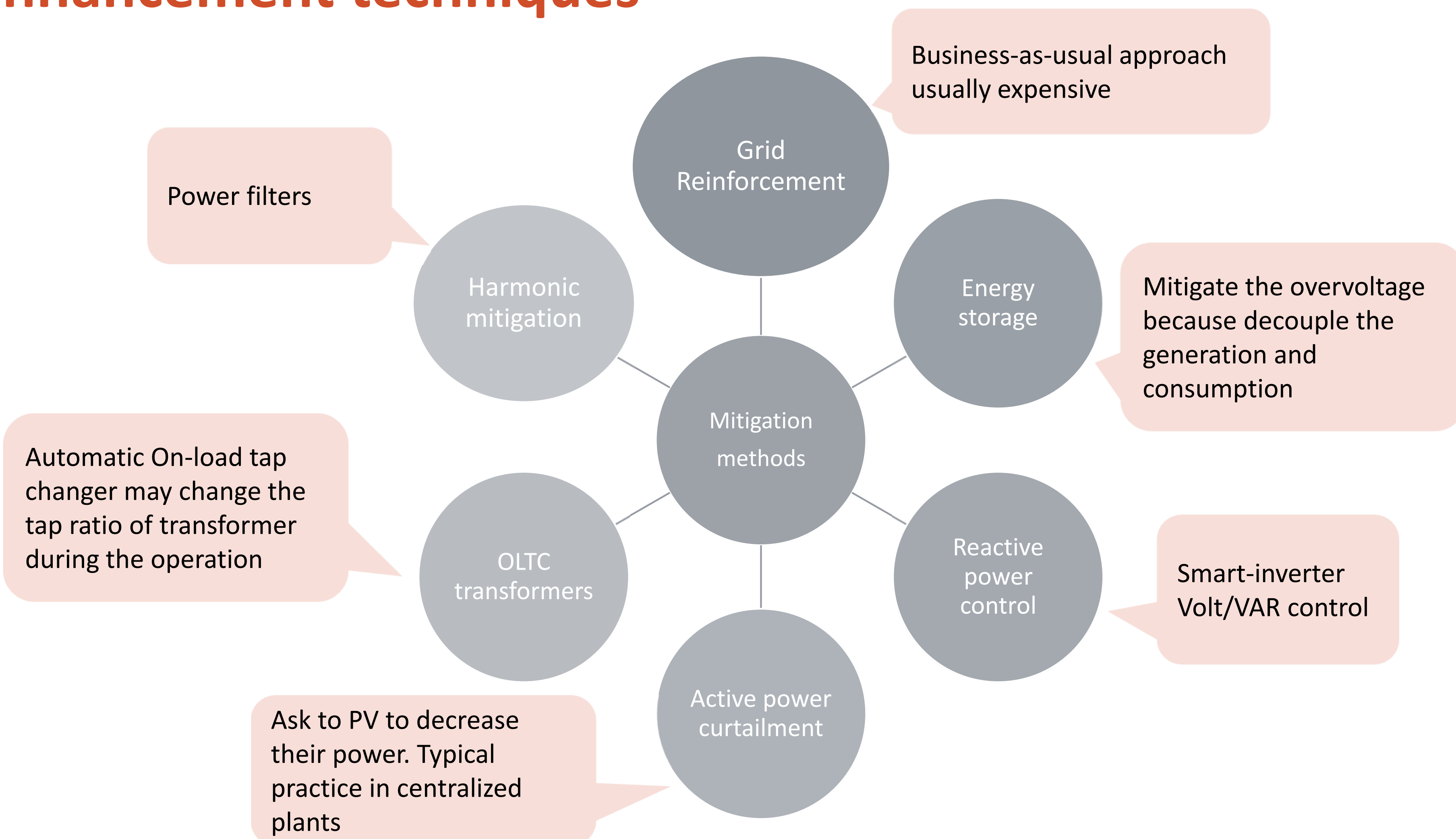


$$Pen = \frac{\sum_{i=1}^{N_{DG}} P_{DG}(i)}{\sum_{j=1}^{N_{load}} \sqrt{P^2(j) + Q^2(j)}}$$

DERs impact on distribution grids



Enhancement techniques



Why HC assessment is a challenging task?

- HC does not lead to a unique solution
- HC is extremely dependent on the available information
- HC can be affected by several uncertainty sources

Uncertainty in PV profiles

Uncertainty in PV size

Uncertainty in load profiles

Uncertainty in PV position

Uncertainty in grid topology

Uncertainty in grid parameters

Hosting capacity approaches

Deterministic

- The maximum power is used for computation.
- Small data required and simple method
- Worst-case scenario which under-estimate the HC
- Calculation time: small

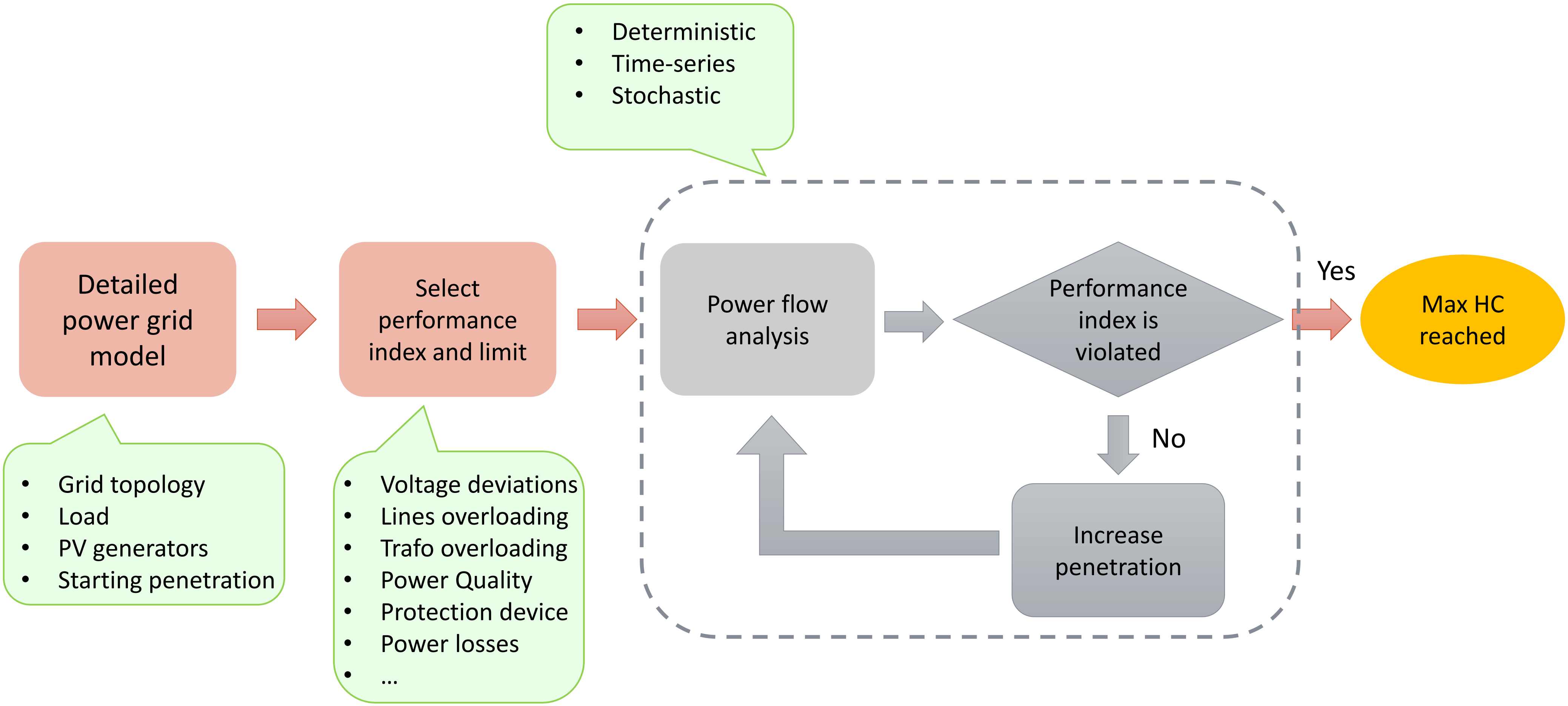
Time-series

- More realistic results of HC due to fluctuations in generation and consumption
- Dependent of available data
- Different scenarios
- Calculation time: moderate

Stochastic

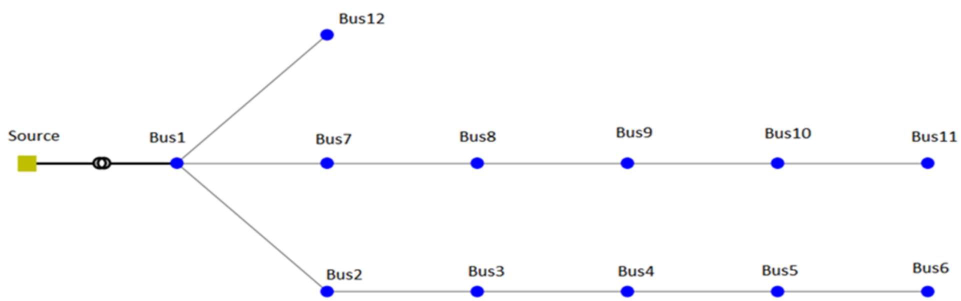
- Many unknown variables are randomized
- Considering several scenarios running Monte Carlo simulations
- Most used method in literature
- Calculation time: large

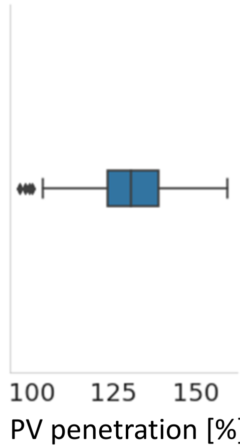
HC general methodology

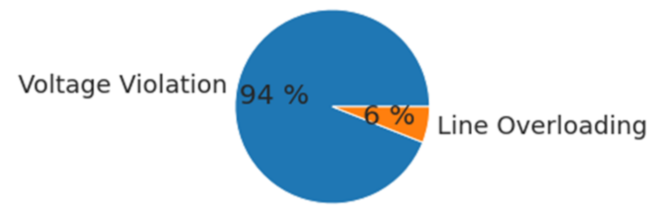


Hosting capacity assessment : an example

European reference low-voltage urban grid[1]



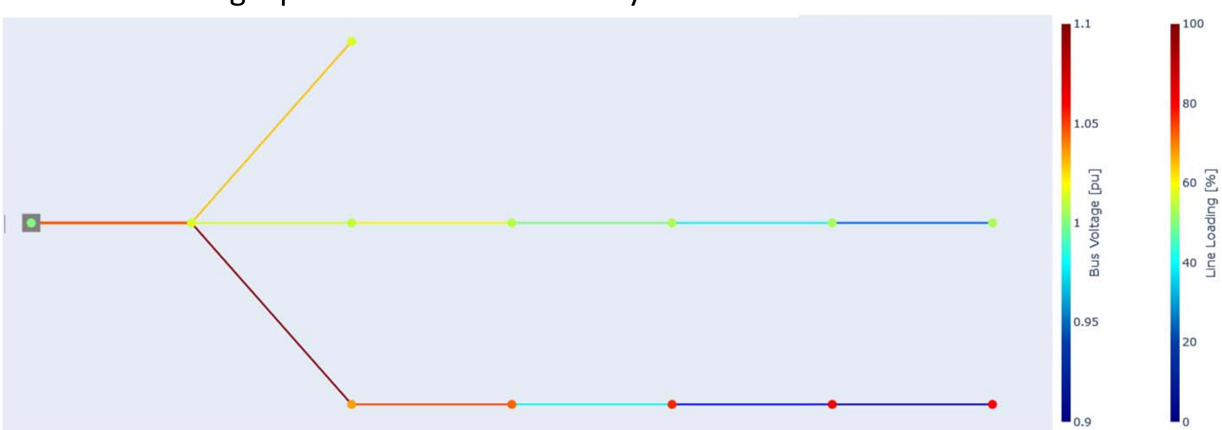




Stochastic Monte-Carlo (1000)

- *PV are placed where there are loads*
- *PV power* $\rightarrow \mathcal{N}(\mu, \sigma^2)$

Results of a single power flow run + PV systems



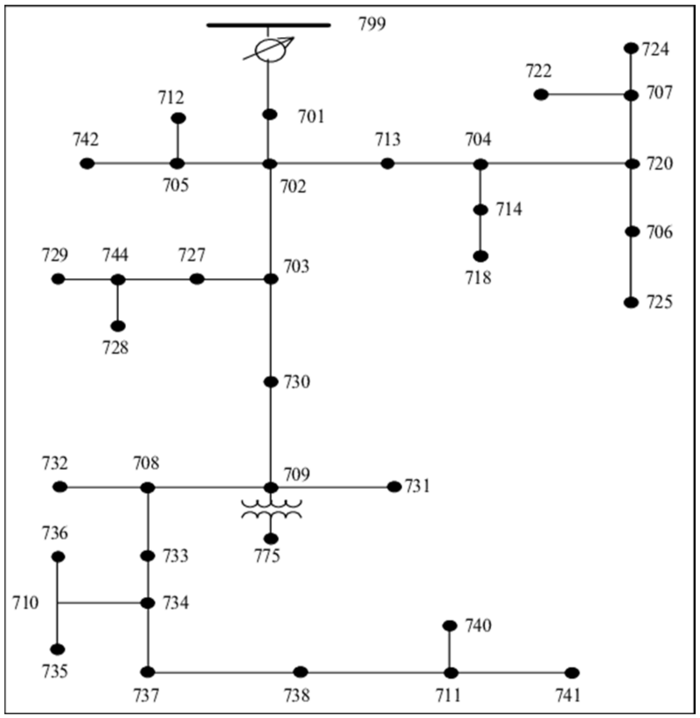
- Overvoltage < 1.05
- Line overloading> 100%
- Trafo overloading >100%

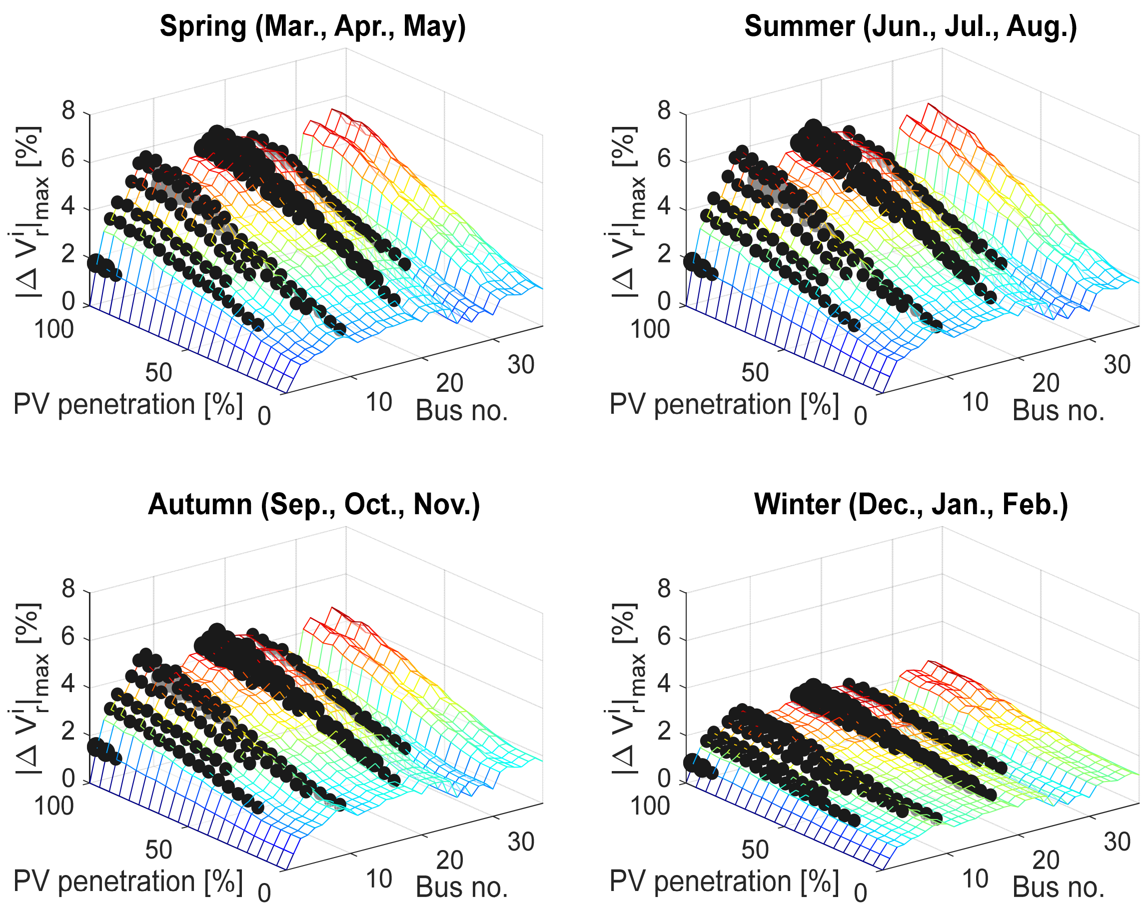
Selected Performance indices

G. PRETTICO, F. GANGALE, A. MENGOLINI, A. LUCAS, G. FULLI, "From European Electricity Distribution Systems to Representative Distribution Networks ", Distribution System Operators Observatory

PV mitigation with optimised PV deployment

Medium voltage IEEE 37-bus system



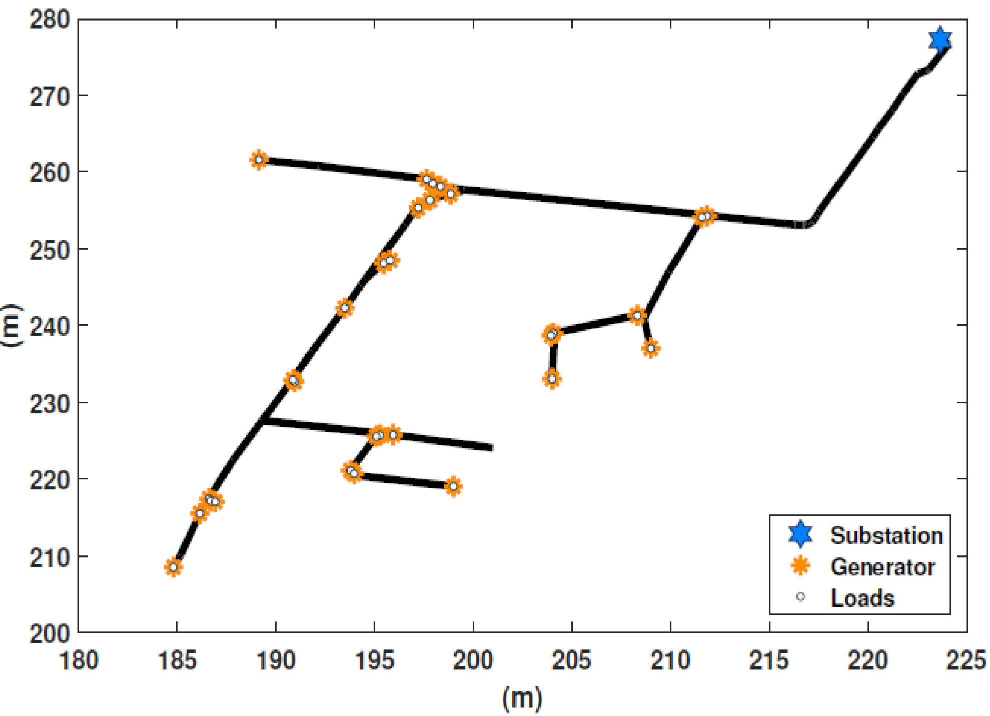


- ➢ Do not reach the hosting capacity

G. Barchi, D. Macii, "A photovoltaics-aided interlaced extended Kalman filter for distribution systems state estimation", Sustainable Energy, Grids and Networks, Volume 26, 2021.

PV mitigation with optimised BESS deployment

UK low voltage distribution grid



➢ Time-series PV hosting capacity assessment with battery energy storage system (BESS) deployment

- **Placement strategies**

1. **Ascending order**: placed one by one from the closest to the farthest bus from the substation in all buses with PV systems

2. **Descending order**: BESS placed one by one from the farthest to the closest bus from the substation in all buses with PV systems

3. **Randomly -1**: BESS placed randomly among buses with PV

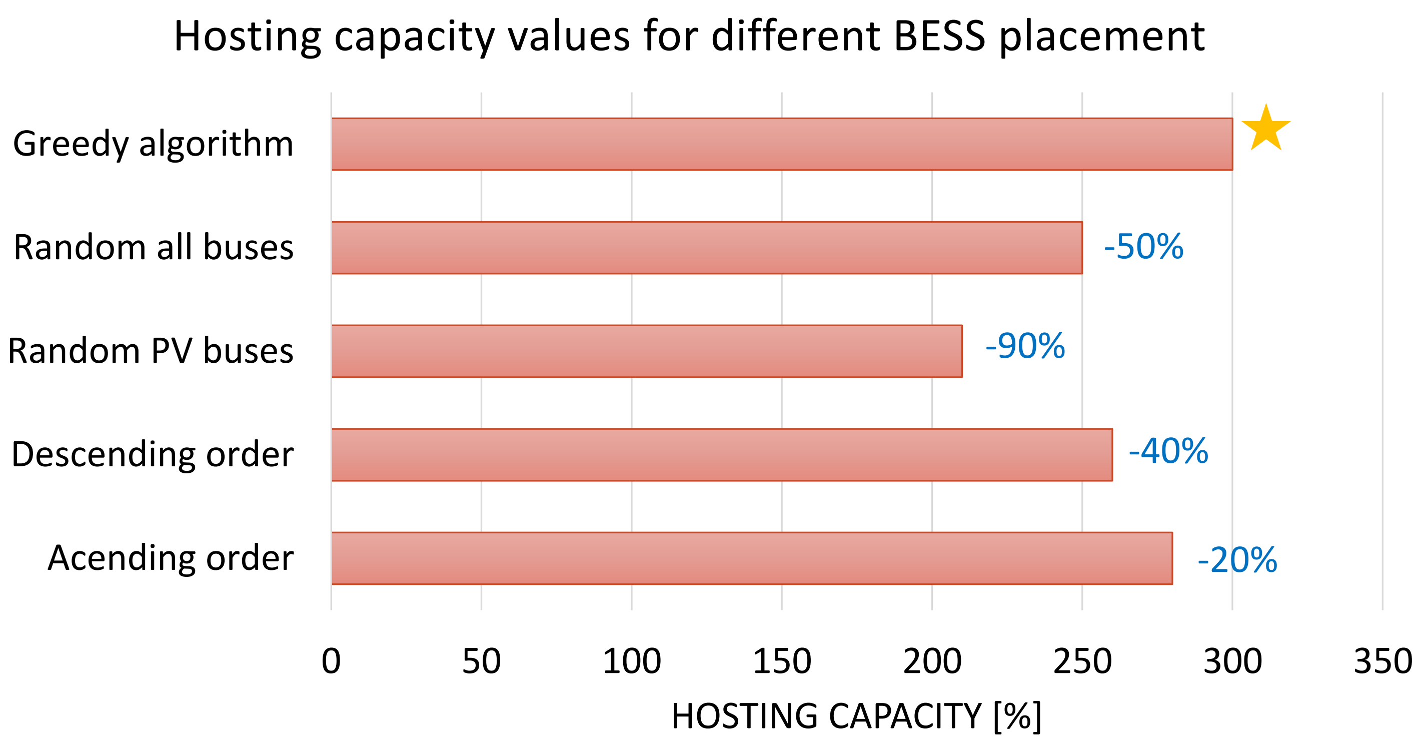
4. **Randomly -2**: BESS placed randomly among the buses (with PV or without PV)

5. **Greedy algorithm**: BESS placed minimizing the voltage deviations

Bartecka, M.; Barchi, G.; Paska, J. Time-Series PV Hosting Capacity Assessment with Storage Deployment. *Energies* **2020**, *13*, 2524.

PV mitigation with optimised BESS deployment

- Comparison of PV hosting capacity for different scenarios (with BESS)



Bartecka, M.; **Barchi, G.**; Paska, J. Time-Series PV Hosting Capacity Assessment with Storage Deployment. *Energies* **2020**, *13*, 2524.

Key messages

- The increase of PV generators is a must to achieve energy independence from fossil fuels and climate neutrality
- Grid hosting capacity might limit the high PV penetration, so it is important to evaluate it
- Adopting mitigation techniques can avoid possible risks in Power System operations caused by PV generators
- PV systems in combination with storage or/and demand-side management (EV, HP) will support to compensate the possible impacts on the distribution system

Thank you for the attention !

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