A FAST HOSTING CAPACITY CALCULATION METHOD FOR LARGE DISTRIBUTION GRIDS

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Background

- There has been a slow but consistent shift in the energy industry from centralized large-scale energy production to distributed localized generation.
- DG technologies provide a set of economic and environmental benefits by:
  - Reducing power generation costs
  - Supporting deployment of DERs
  - Increasing the systems' overall energy efficiency
- The increased integration of DGs into existing distribution networks is impacting their behavior in terms of:
  - Voltage profile
  - Reliability
  - Power quality

Hosting Capacity

- To prevent these adverse impacts, a determination of the network's **hosting capacity** is required.
- The term "**hosting capacity**" is the maximum DG capacity that a distribution network can accommodate without violating recommended operating constraints.
- By optimizing the hosting capacity, electric utility can incorporate more DGs without requiring any system upgrades and/or new investments.

Work Motivation

- Traditional optimization of DGs in distribution networks is computationally intensive for two reasons:
  - **Nonlinearity**: Optimizing DG hosting capacity involves nonlinear AC power flow analysis that relies on nonlinear solvers with undesirable long runtimes
  - **Large search spaces:** Each bus can accommodate DG and will contribute an independent variable to the search space (the number of DG profiles grows with the number of active buses)
- These computational requirements make them impractical in many real-world conditions.

Work Motivation (cont'd)

- This work addresses these issues by using a sensitivity-based method focused on voltage and line flows to reduce the complexity of calculations.

- The proposed method uses an optimization approach that:
  - Reduces the number of variables in the search space
  - Avoids extensive iterations, and significantly reduces the runtime
  - Provides comparable results with traditional methods

- The smaller computation time allows electric utility to scale up the optimization to larger systems without losing the robustness.

Sensitivity-based Method Problem Formulation

- The objective:
  - To maximize the amount of DG hosting capacity without negatively affecting the operational performance of the network

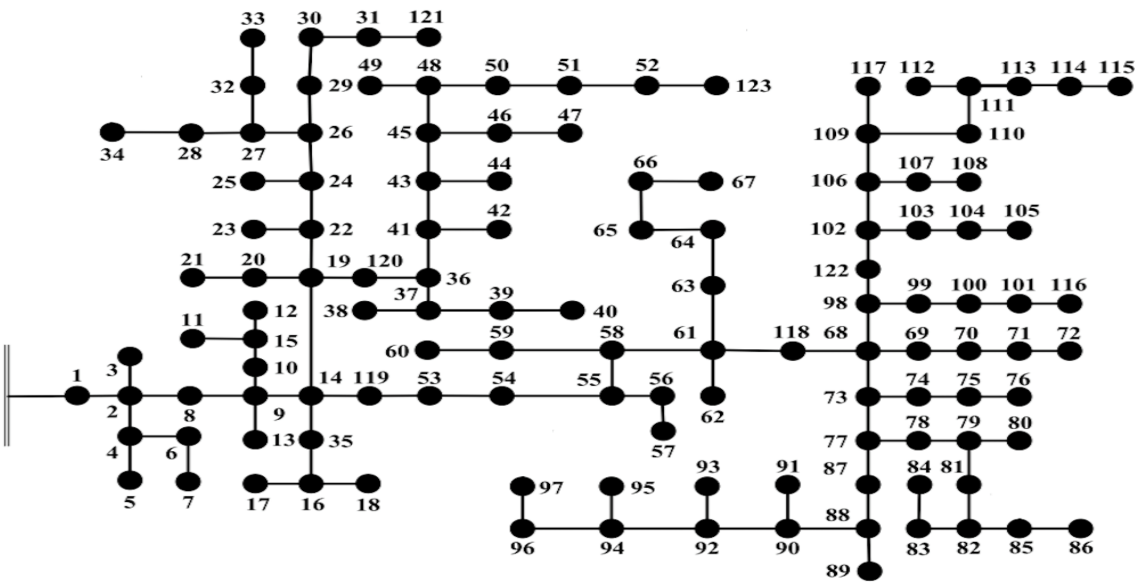
- Subject to:
  - **The line capacity limits** is defined based on the line sensitivity factors (**LSFs**) and subject to the power injection at the considered bus subject to the power injection at
  - **The voltage magnitude limits** is defined based on the voltage sensitivity factors (**VSFs**) with respect to the active and reactive injected power

Sensitivity-based Method Problem Formulation (cont'd)

- The net injected active and reactive power is defined as the power generated by DG minus the load at the considered bus.
- The uncertainties in load are integrated into the model through adjusted line and voltage limits.
- This model has only one variable(DG output power), so it can be solved in a very short amount of time even for very large-scale problems.

Numerical Results

- The IEEE 123-bus distribution test system is used to show the performance of the proposed method.
- Two different scenarios are performed using two different load conditions:
  - Base-load values (typical load conditions)
  - Uncertain-load values (worst-case load conditions)



The IEEE 123-bus distribution system.

Case 1: Comparison with the iterative method

- In iterative methods, to analyze the impact of DG integration with DG power increments of 1 kW:
  - **In a single bus**: It would take more than **18 minutes**
  - **In all buses at the same time**: It would take more than **10 days**

- In the proposed sensitivity-based method:
  - **In a single bus**: The highest deviation in results is obtained as **5.42%**
  - **In all buses at the same time**: The difference is 4.56 %
  - The time required to determine the individual and grid DG hosting capacity is less than **2s**

The individual DG hosting capacity in selected buses using Base-load values

Bus Number	Hosting capacity using traditional iterative method (MW)	Hosting capacity using the proposed sensitivity-based method (MW)
4	6.564	6.218
63	2.862	2.686
98	2.990	2.831

Case 2: Impact of load variations

- The proposed method is used to calculate the optimal hosting capacity for both base and uncertain load scenarios.
- The load uncertainty reduces the optimal hosting capacity by **19.5%.**
- The overall runtime of the entire problem is less than **2s.**

Optimal hosting capacity results for base-load and uncertain-load

Bus Number	Base-load hosting capacity (MW)	Uncertain-load hosting capacity (MW)
2	1.641	1.156
3	3.632	0.0
5	3.984	1.215
7	0.0	3.966
117	0.0	0.721
121	2.111	2.093
Total DG (MW)	**11.368**	**9.151**

Conclusion

- A sensitivity-based hosting capacity method was proposed to determine the optimal DG profile in an active distribution network.
- The advantage of using the sensitivity analysis was shown to be a reduction in the optimization complexity and accordingly the computation time.
  - This allows to scale-up the analysis to larger systems without requiring long runtimes
- Load uncertainty was considered to show the dependence of the hosting capacity on load variations as well as improving the robustness of DG integration.

Thank you