Calculating PV Hosting Capacity in Low-Voltage Secondary Networks Using Only Smart Meter Data

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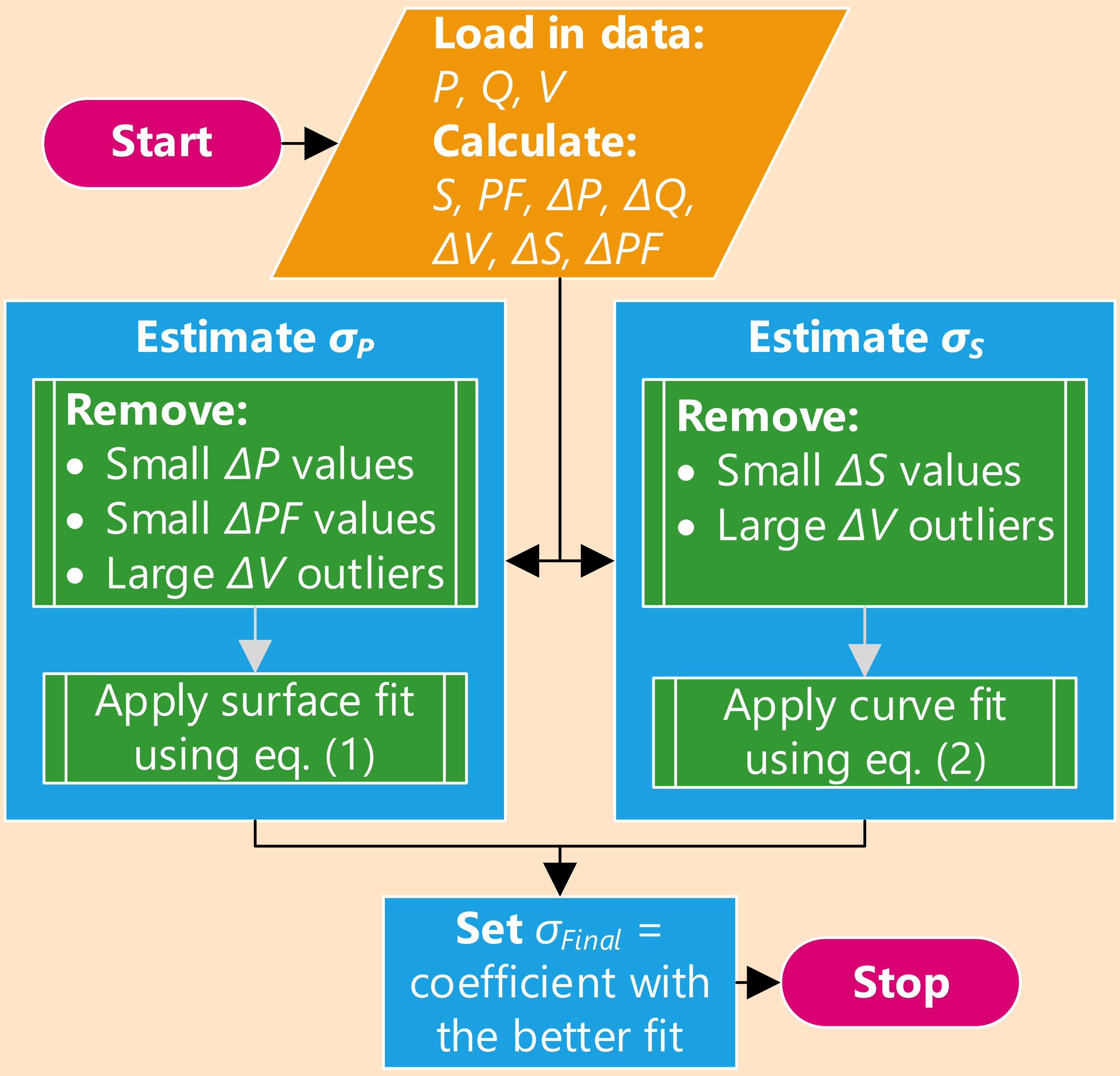
Abstract:

- Conventional PV hosting capacity (HC*) analysis requires detailed grid models and time-consuming simulations
- Grid models of low-voltage secondary networks (where most residential PV systems are installed) are often over-simplified or non-existent
- A model-free approach is proposed in this work that calculates the voltage-constrained PV HC using only smart meter data (P, Q, and V measurements)
- The approach was evaluated on two different datasets of actual utility smart meter data representing 2,700+ customers
- Model-free results were compared to conventional model-based results for those same customers

*HC is the amount of PV that can be installed at a specific location given the current network configuration

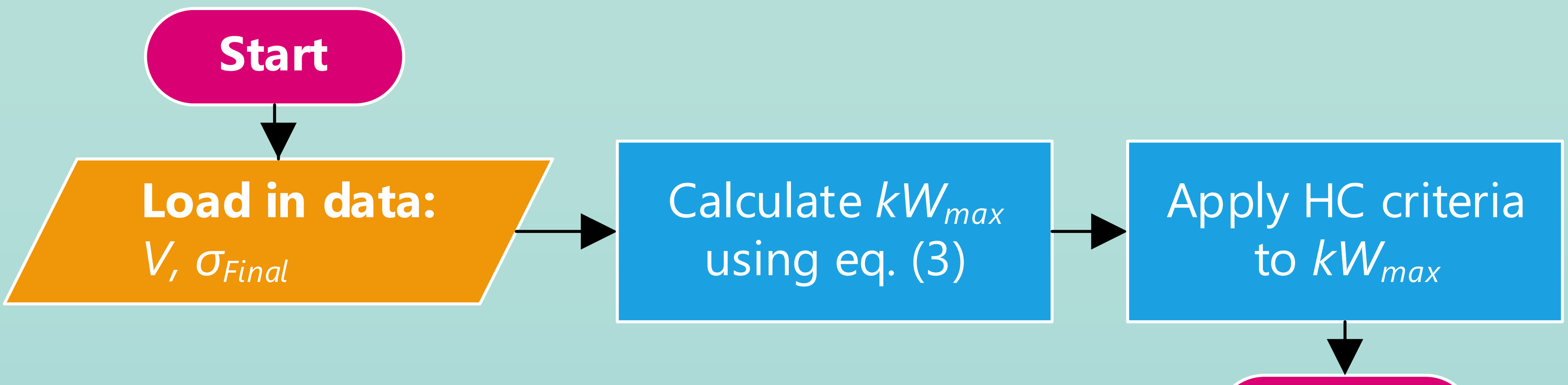
Determine Voltage Sensitivity Coefficient:



$$\Delta V = c_1 + (\sigma_P * \Delta P) + (\sigma_Q * \Delta Q) \quad (1)$$

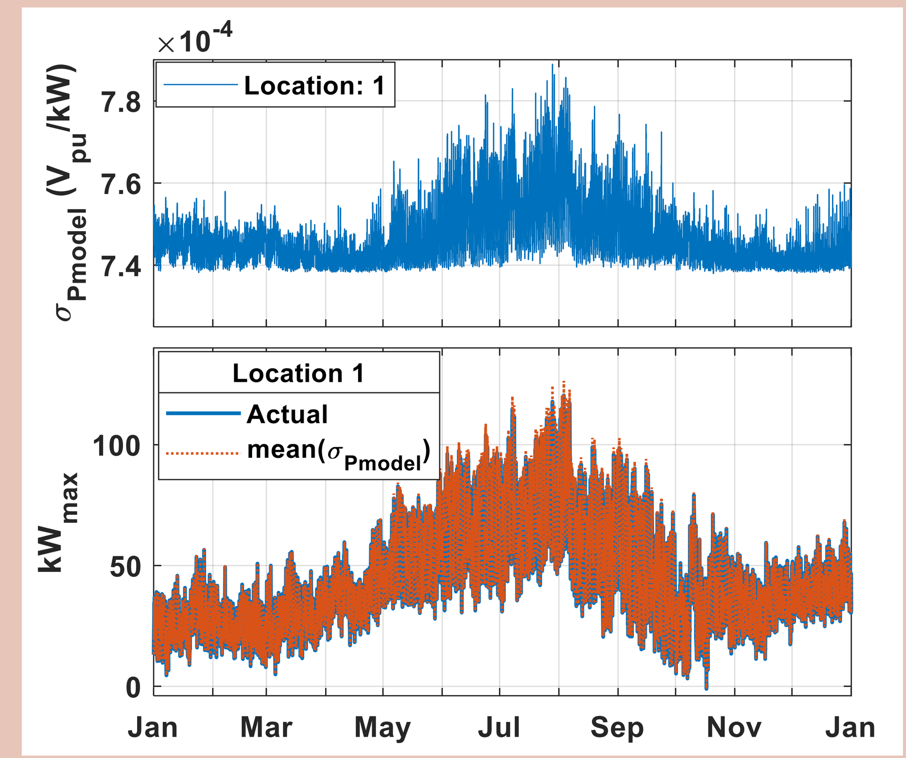
$$\Delta V = c_2 + (\sigma_S * \Delta S) \quad (2)$$

Calculate Voltage-Constrained HC:



$$kW_{max}(t) = (V_{limit} - V(t))/\sigma_{Final} \quad (3)$$

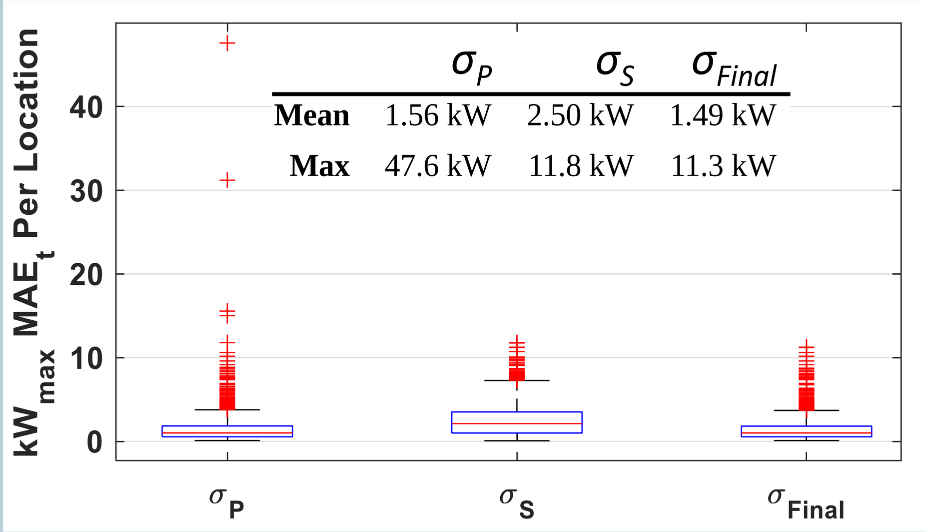
Impact of Using a Constant Voltage Sensitivity Coefficient:



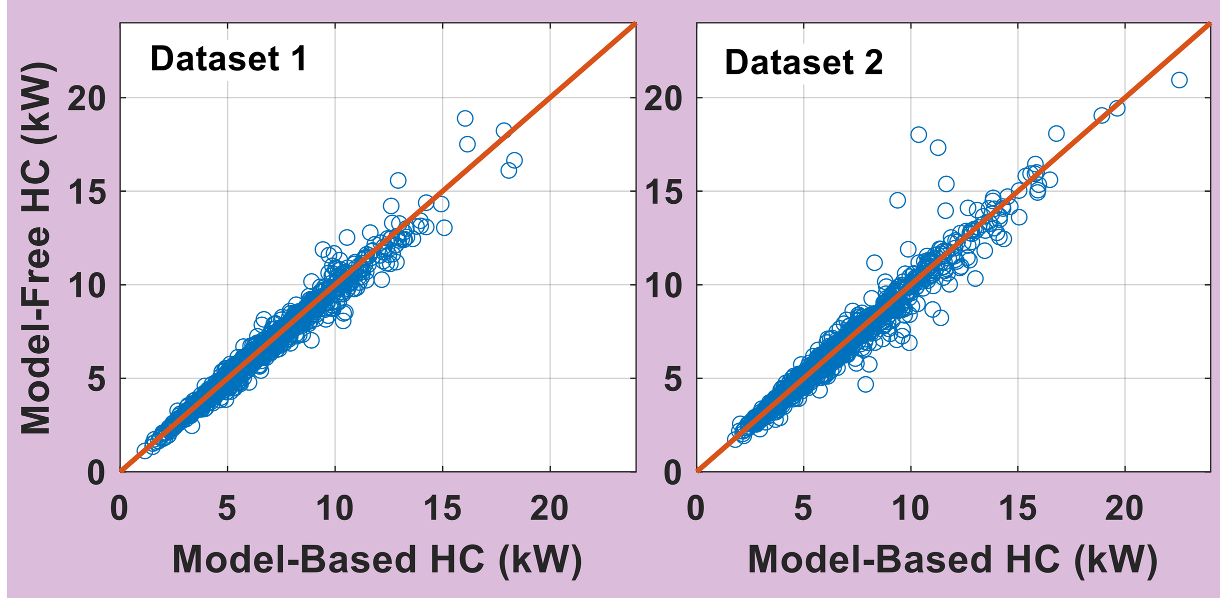
- Voltage sensitivity at a location (σ_{Pmodel}) varies through time as loading and grid conditions change
- Using mean(σ_{Pmodel}) to find the max allowable kW injections resulted in an average of ±0.33 kW error—i.e., about ± a single PV module difference

Importance of Selecting the Coefficient Value:

- σ_P is the most precise but prone to error if ΔP and ΔQ are too correlated
- In that case, σ_S can be a reasonable alternative. Distribution grids often have low X/R ratios, so ΔS≈ΔP≈ΔQ
- On average, using the σ_{Final} values resulted in the lowest errors

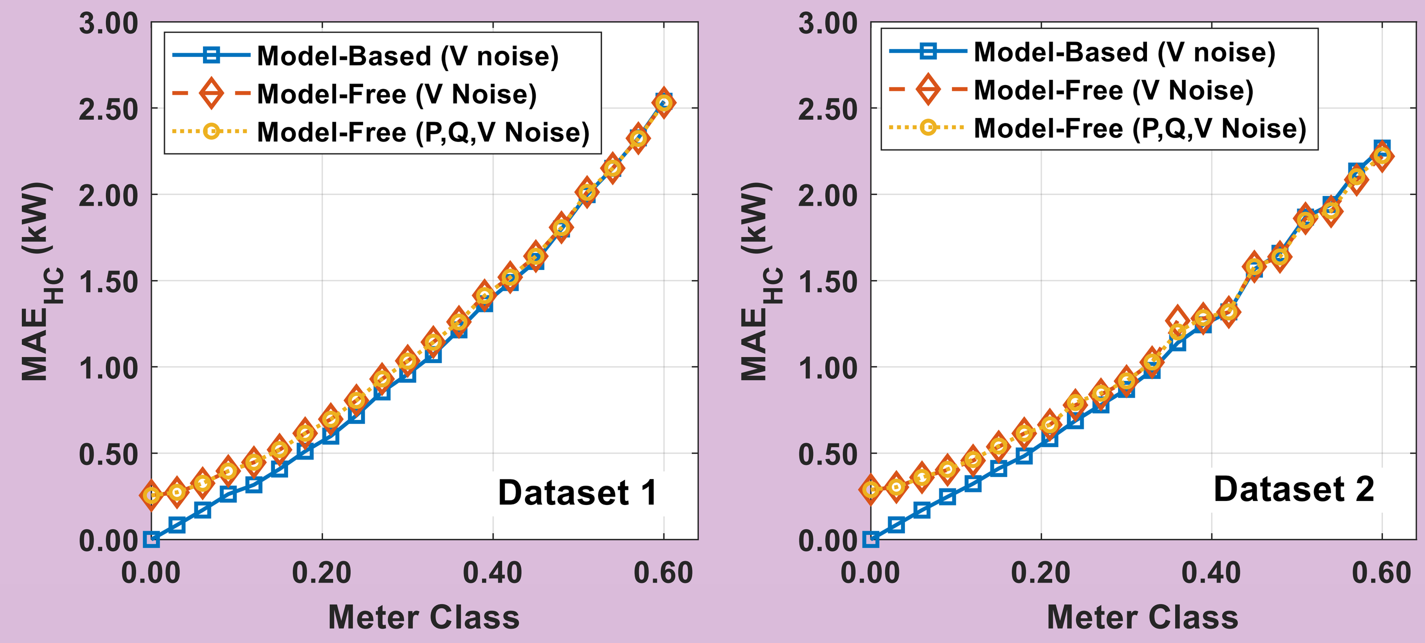


Model-free vs. Model-based Hosting Capacity Results:



Metric	Dataset 1	Dataset 2
MAE_{HC}	0.26 kW	0.29 kW
Max. Error	2.84 kW	7.65 kW
Locations w/ <1kW Error	96.6%	95.8%

Sensitivity to Measurement Noise:



Conclusions:

- The proposed method was accurate within 0.30 kW (MAE) of model-based results across two different smart meter datasets
- Model-free and model-based HC methods were equally sensitive to measurement noise
- Model-free method required significantly less computational time, where results were calculated in minutes instead of multiple days

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