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IMPACT ASSESSMENT OF A HIGH PENETRATION OF ROOFTOP PV IN CAPE TOWN

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City of Cape Town

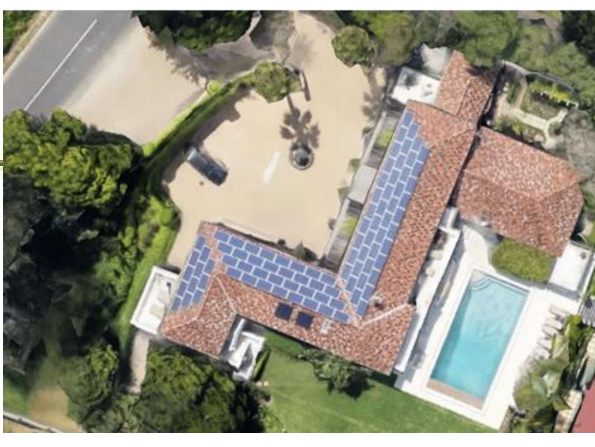


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Introduction

- NRS 097-2-3: 2014 specifies the capacity limitations for shared LV connections
 - Is this overly restrictive?
 - May this result in QOS violations?
- Will CCT first run out of roof space, or wires?
- Study by Eskom, CCT, US, UCT, CPUT



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- Methodology
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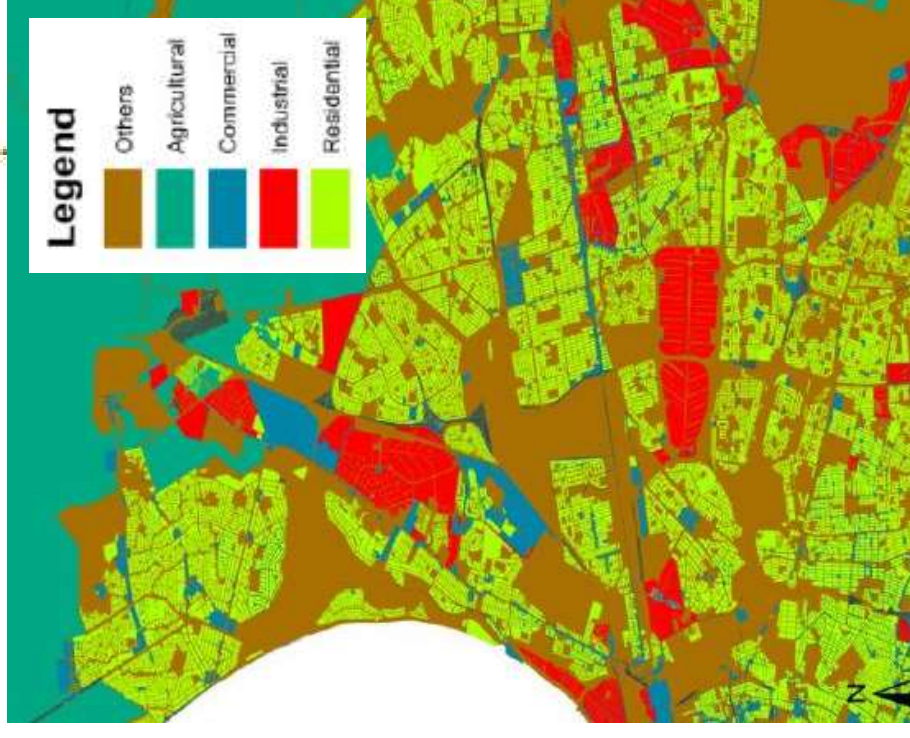
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Scope

1. Existing urban networks
 2. PVDG randomly distributed, restricted by roof space and circuit breaker
 3. Generation back into the network, no battery storage
- ☞ Focus on residential only



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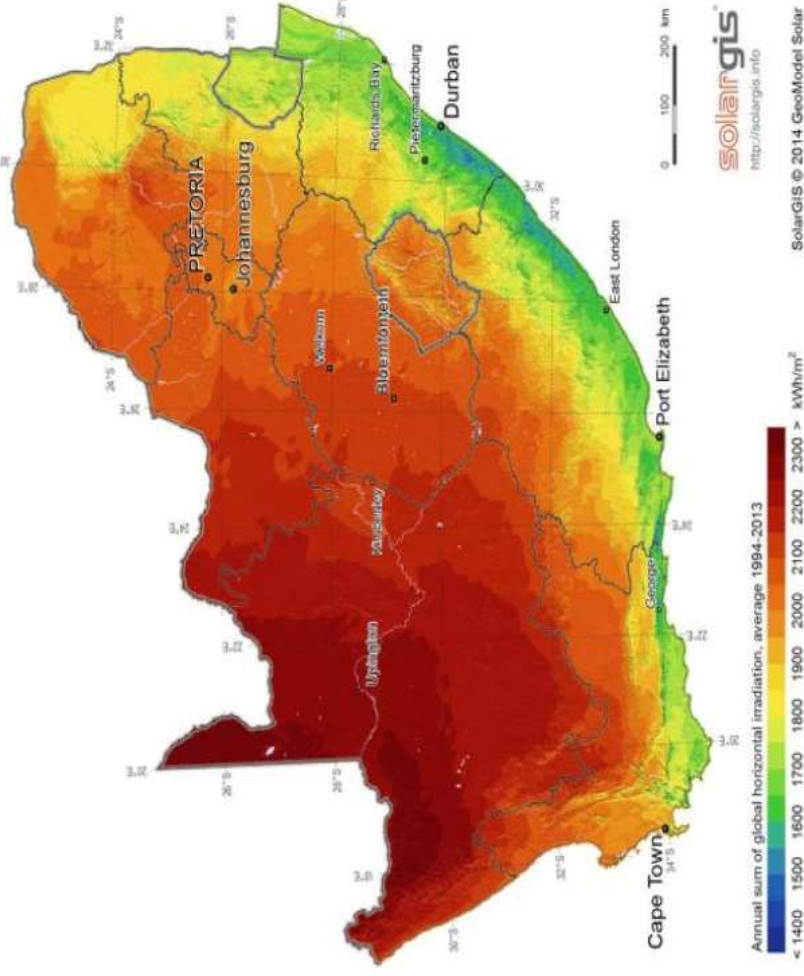
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Methodology – Network selection (1)

1. Solar resources



2. Land use



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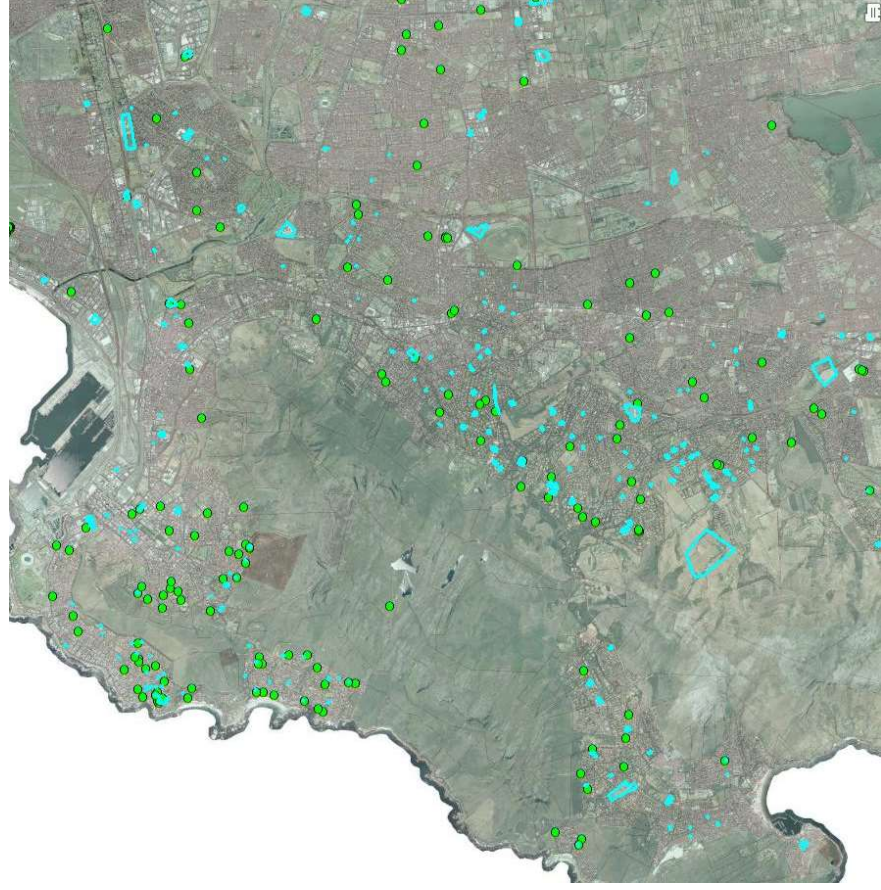
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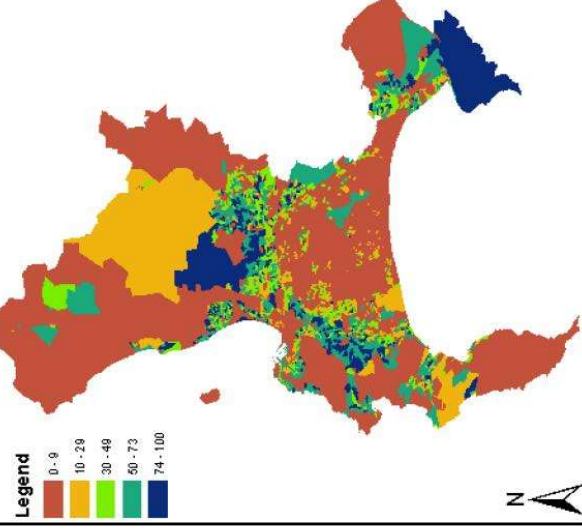


Methodology – Network selection (2)

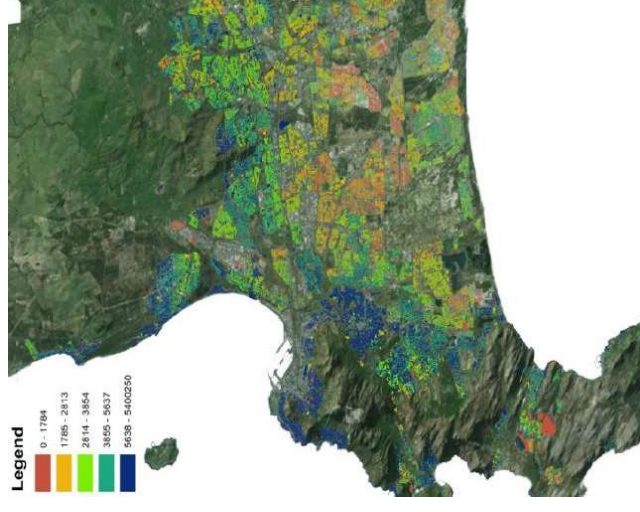
Existing Rooftop PV



3. LSM



4. Property value /m²



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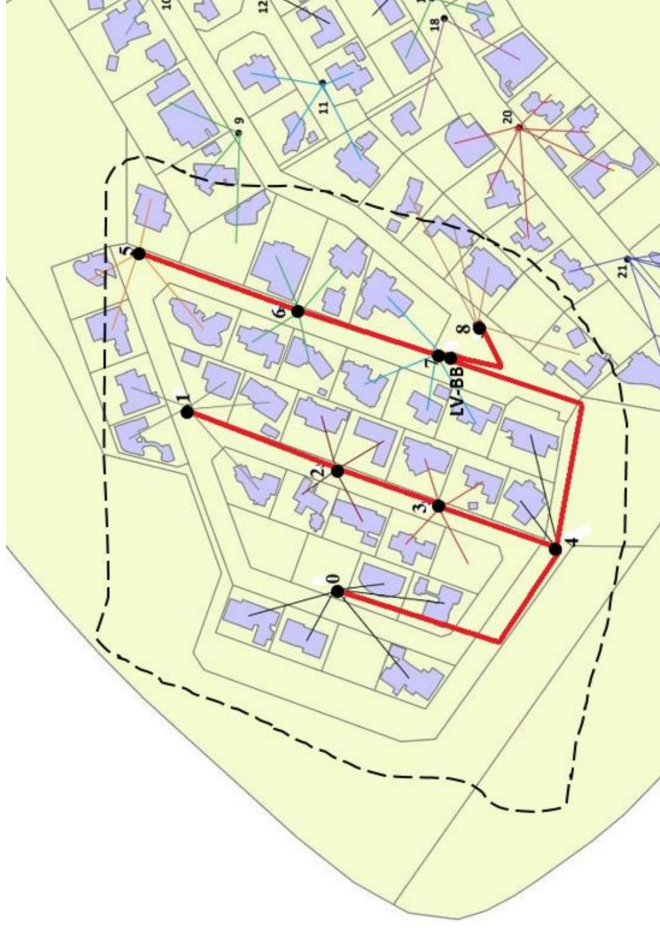
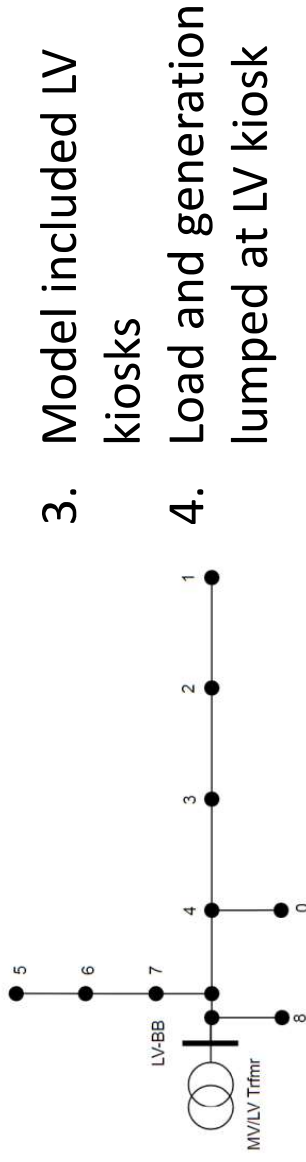
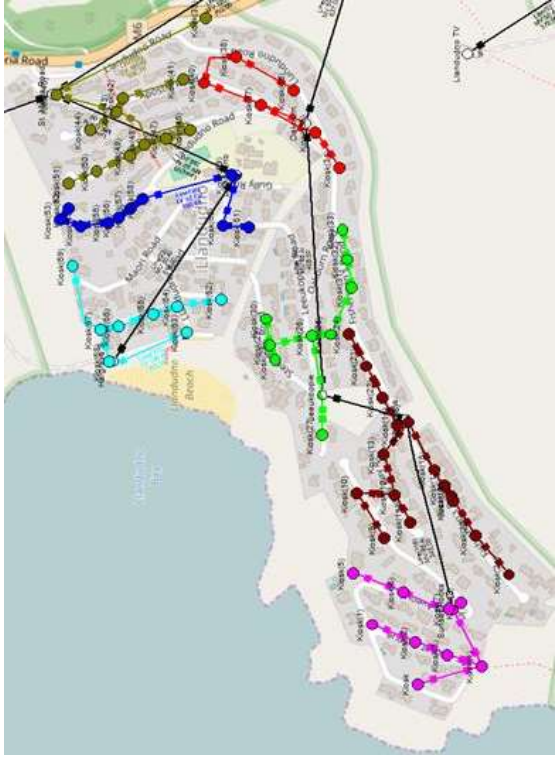
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Methodology – Network modelling

1. Separate LV networks (7)
2. 30- 53 customers each



5. Property is allocated to the nearest LV kiosk
6. Connections are distributed across phases

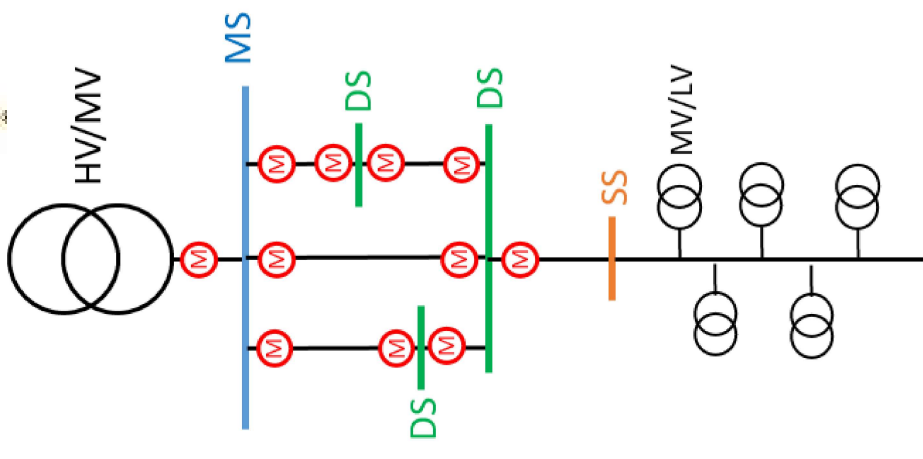
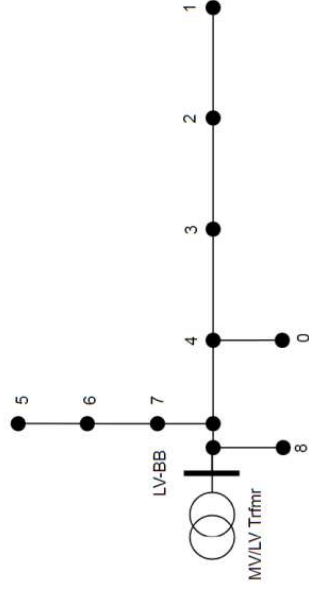
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Methodology – Load modelling (1)

- No load data at LV level
- The MV feeder peak load -> ADMD for each MV/LV transformer using its capacity rating
- ADMD per MV/LV transformer -> ADMD per customer using the property size as scaling factor.



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Methodology – Load modelling (2)

- Due to uncertainties in power system variables (e.g. stochastic customer load variations), deterministic load models are inadequate.
- Probabilistic load flow (PLF) techniques can be used to model the uncertainties and provide a set of load flow results.
- This requires the development of statistical load models.
- The ADMD models were developed into statistical models using a CCT internal standard (consistent with NRS034), considering the Herman Beta methodology.

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Methodology – Generation modelling

- PVDG is randomly located on the network (node and phase)
- The allocation process is bounded by two factors:
 - Desired penetration level,
 - Maximum Solar Hosting Capacity (available roof space of each property, or circuit breaker rating).
- The statistical parameters for PVDG generation profiles are based on models derived in previous research (beta pdf of current at unity power factor and of spike-shape distributions).

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Methodology – Summary

- Probabilistic approach required, to consider non-deterministic characteristics

a) stochastic variability in the load
b) variability in the PVDG output

Herman-Beta-
Extended transform

c) the uncertainty associated with
PVDG location (or uptake)
d) the uncertainty of the size of the
installed PVDG system

Monte-Carlo Simulation

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Simulation Methodology (1)

$$\% PV Penetration = \frac{\sum_{i=0}^N PV_{Rated\ i} (kW)}{Feeder\ MD\ (kVA)} \times 100\%$$

Feeder MD : Maximum load the feeder can supply before network violations

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Simulation Methodology (2)

The simulation methodology followed :

- 1 Determine the **Feeder MD**: Using the winter load, increase the load and determine the highest passive loading it can supply without violating the design voltage limit .
- 2 Using the summer load model, **randomly allocate PVDG** modules and calculate the voltage rise and conductor thermal loading. Repeat for different placement scenarios (800 runs).
- 3 **Add further PVDG modules**, repeating c) with each increment, until the feeder is 'full'.
- 4 **Plot** the results of calculated voltages and line currents against the penetration ratio on a scatter plot.
- 5 Derive the maximum **hosting capacity** from the scatter plots

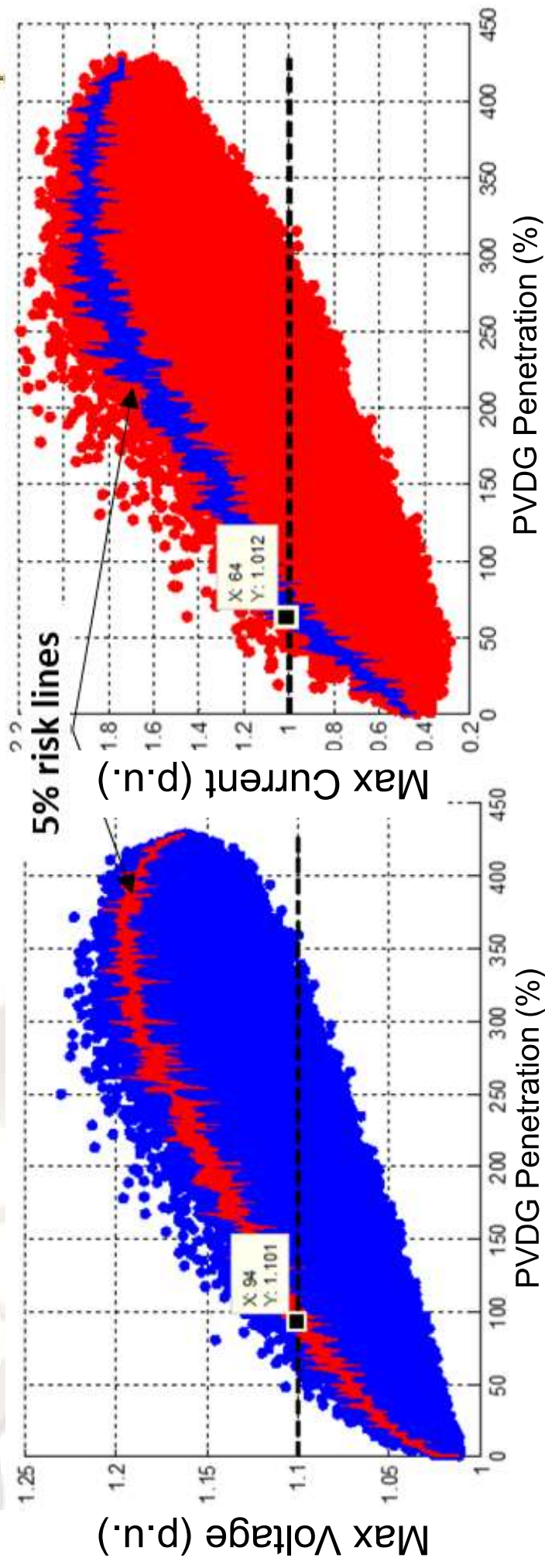
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Results



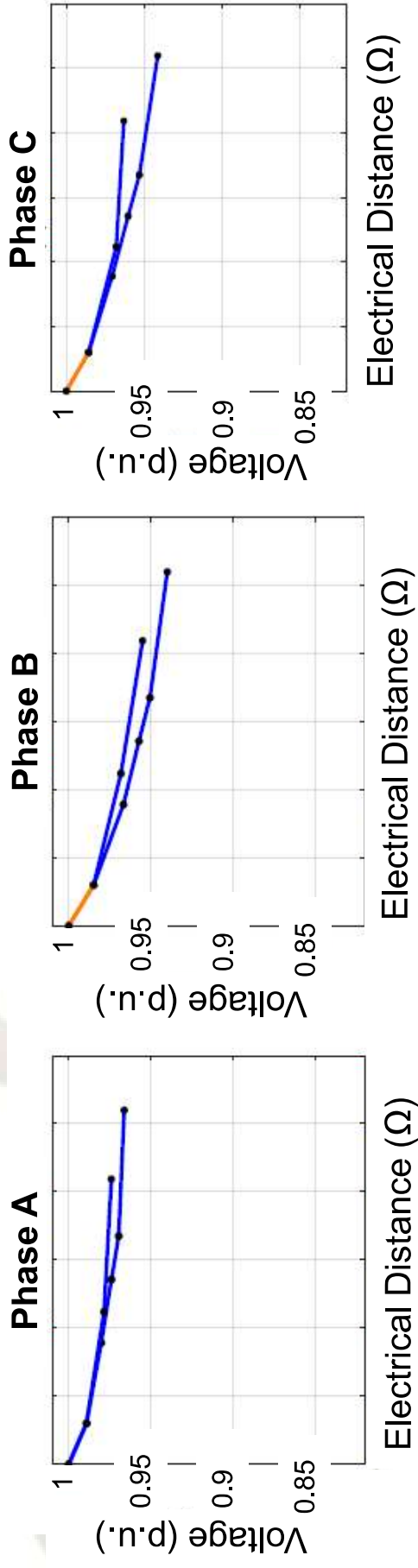
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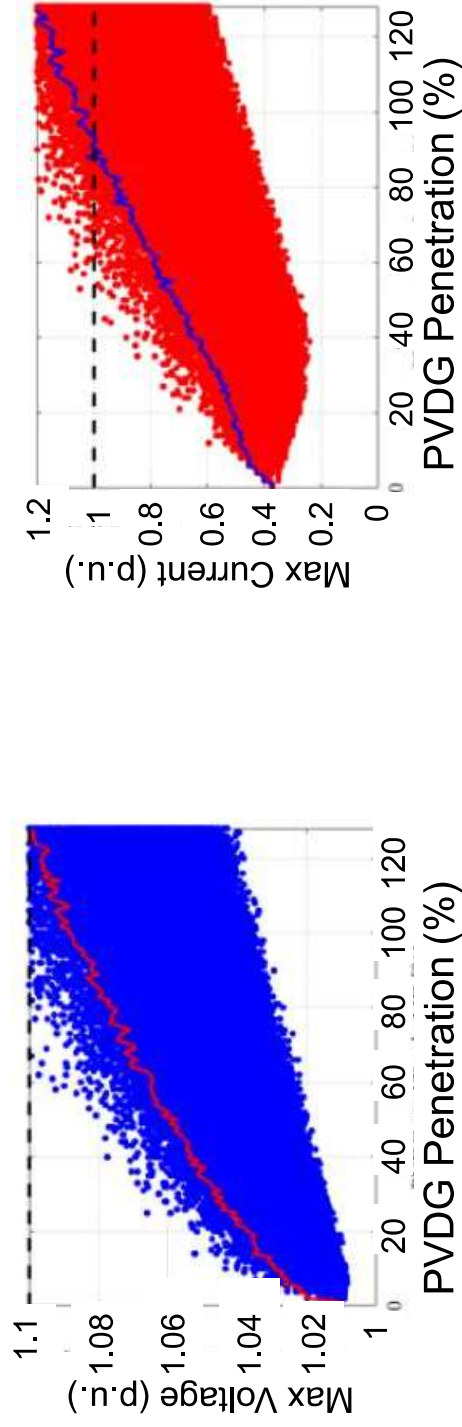


Results – Highest PV penetration

Passive feeder:



Active feeder:



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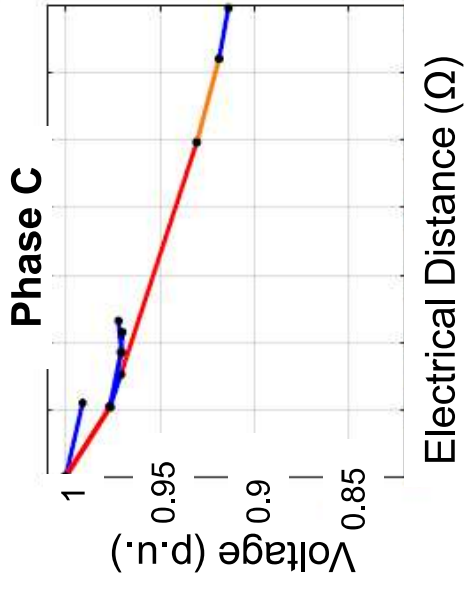
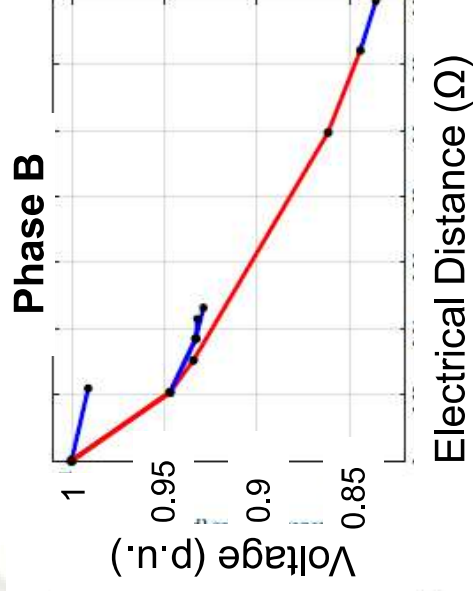
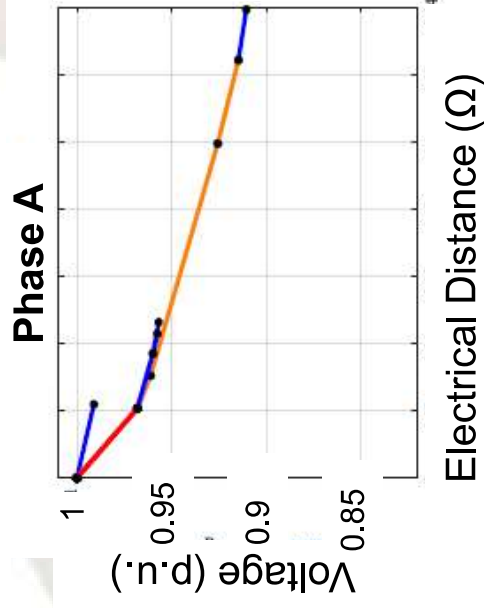
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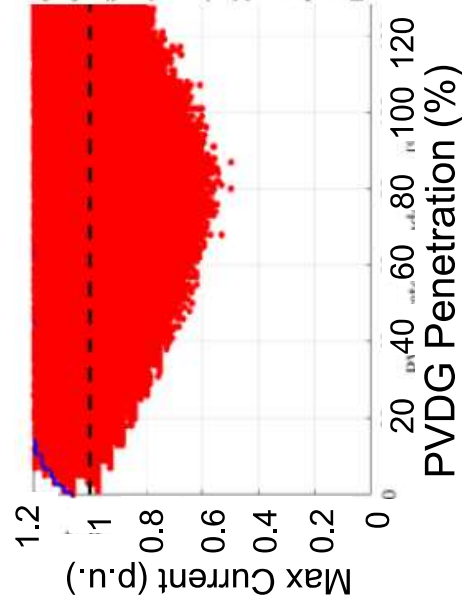
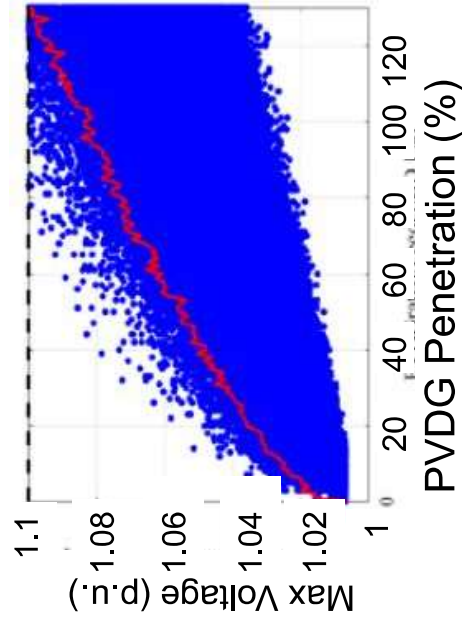


Results – Lowest PV penetration

Passive feeder:



Active feeder:



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Conclusions – Benefits

- A methodology was developed
- Better understanding of PVDG problems



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Conclusions – Penetration limits

- Feeder specific PVDG penetration limits:
 - Residential roof space > urban residential feeder capacity
 - Some feeders can accommodate no PV
 - Feeders operating within their limits $\pm 7\text{kWp/hh}$
 - Penetration limit increases if PVDG is limited per household
 - Balanced networks can accommodate more PV than unbalanced networks



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Conclusions – Way forward

- Results are based on a particular feeder and cannot be extrapolated
- There is a need for new design guide



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Acknowledgement

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Thank you

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