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The 4th Industrial Revolution ("4IR") | *Building the Power Utility of the Future, Today*

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

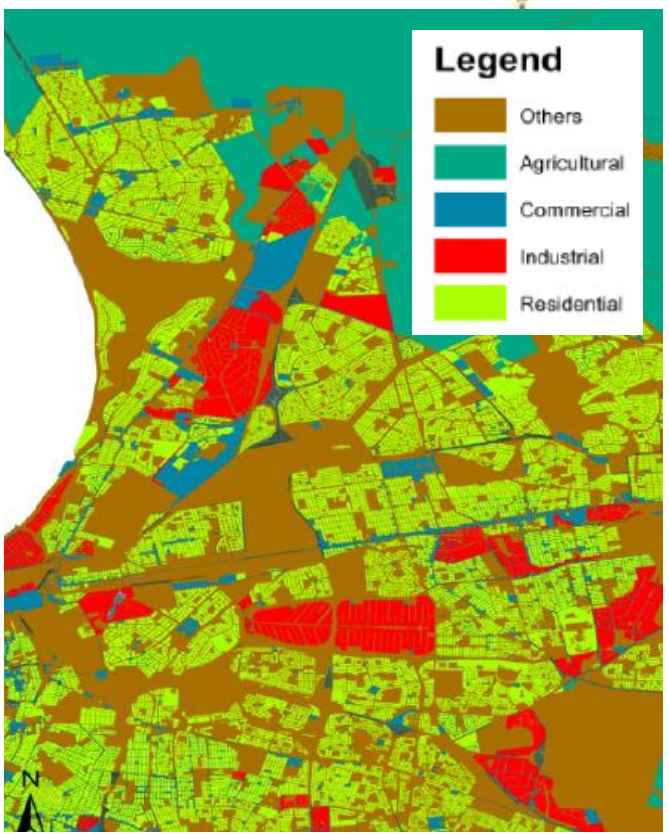
Contents

- Scope
- Methodology
- Results
- Conclusions

Scope

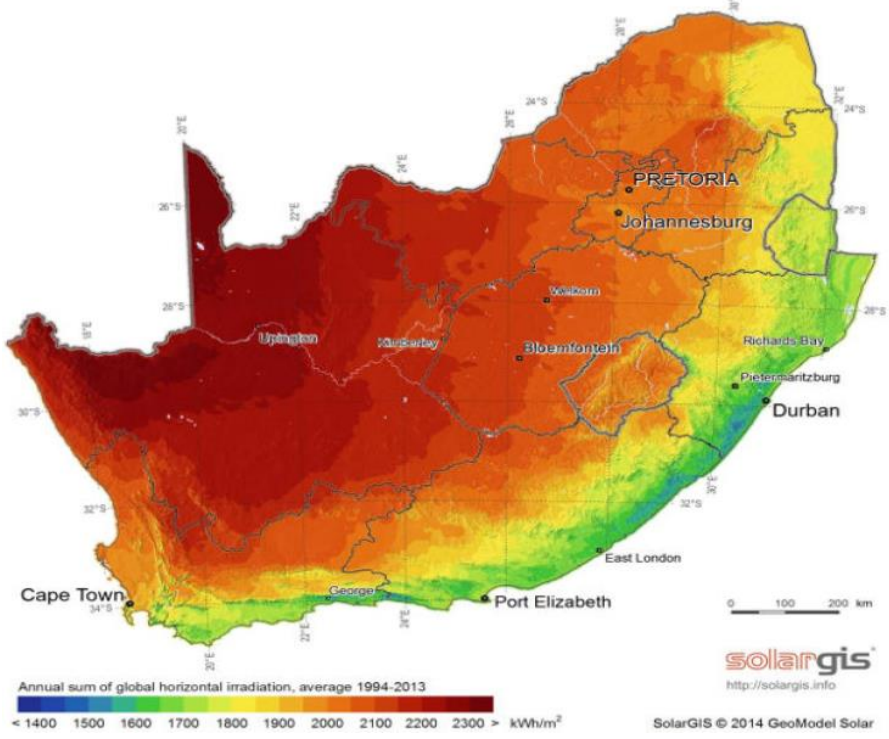
1. Existing urban networks
2. PVDG randomly distributed, restricted by roof space and circuit breaker
3. Generation back into the network, no battery storage

☞ Focus on residential only

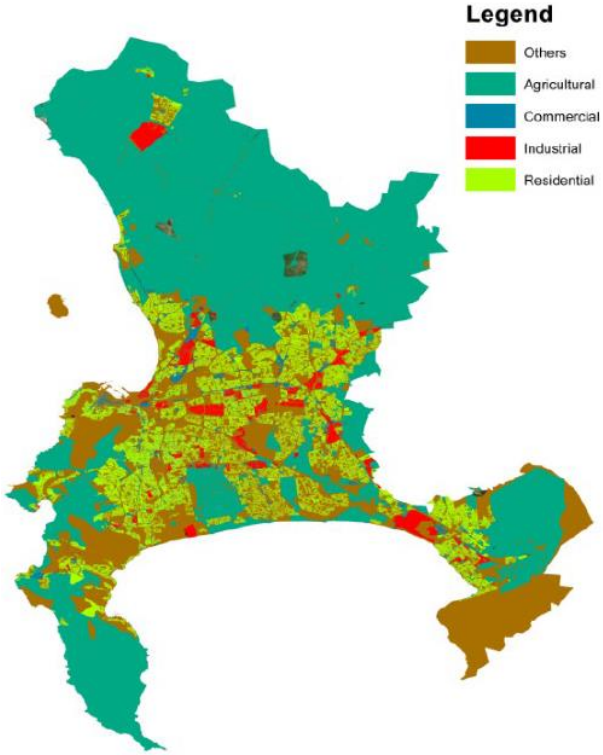


Methodology – Network selection (1)

1. Solar resources

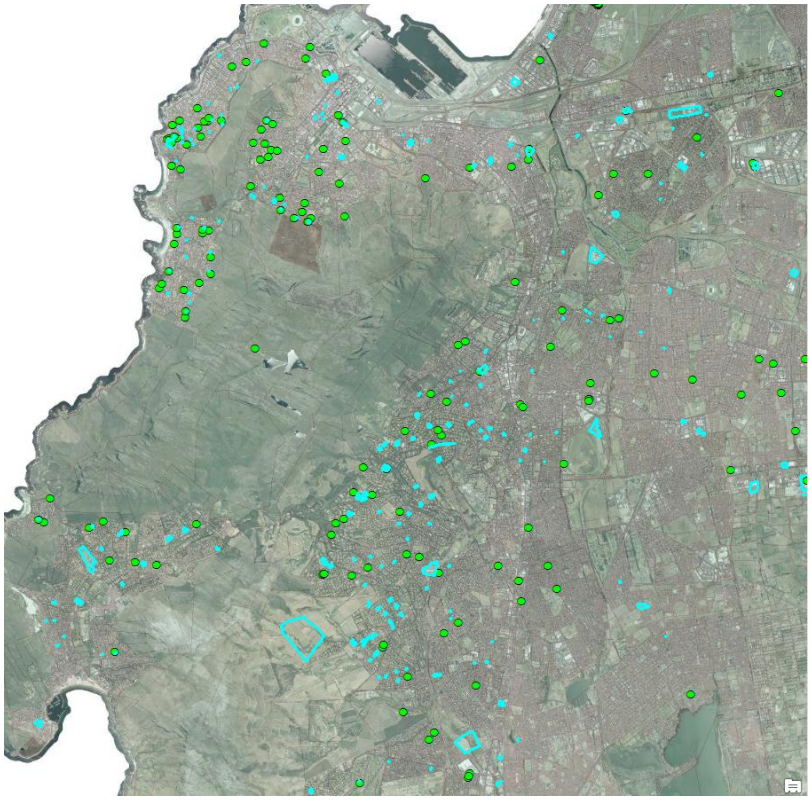


2. Land use

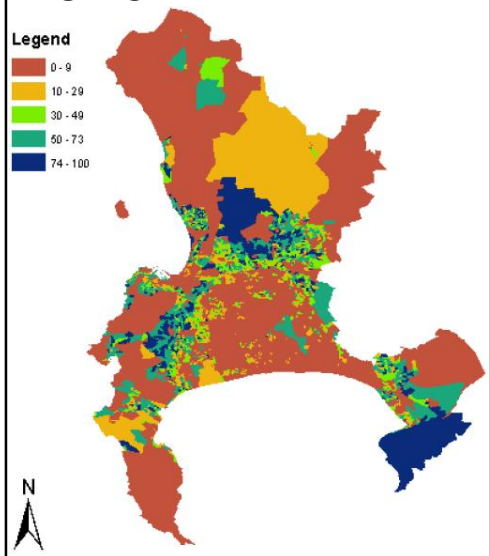


Methodology – Network selection (2)

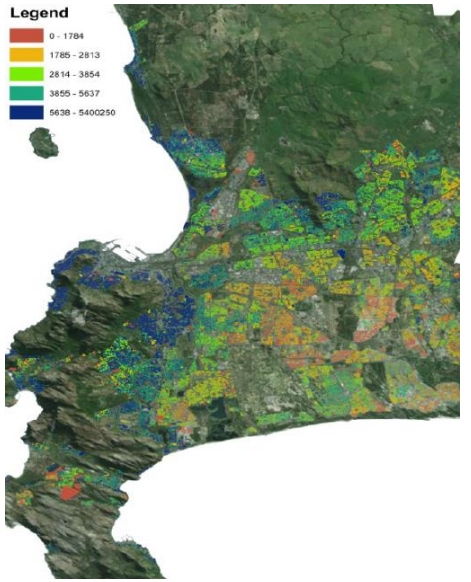
Existing Rooftop PV



3. LSM

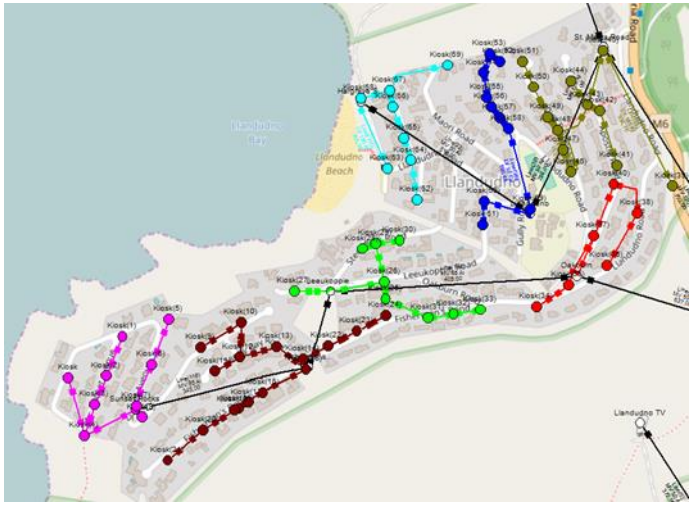


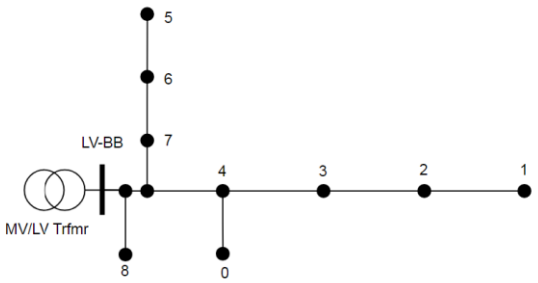
4. Property value /m^2



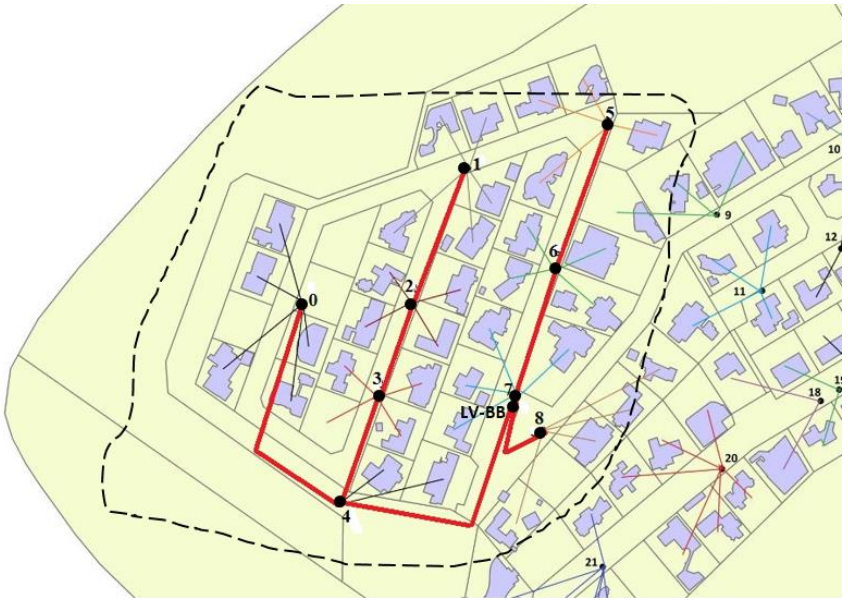
Methodology – Network modelling

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





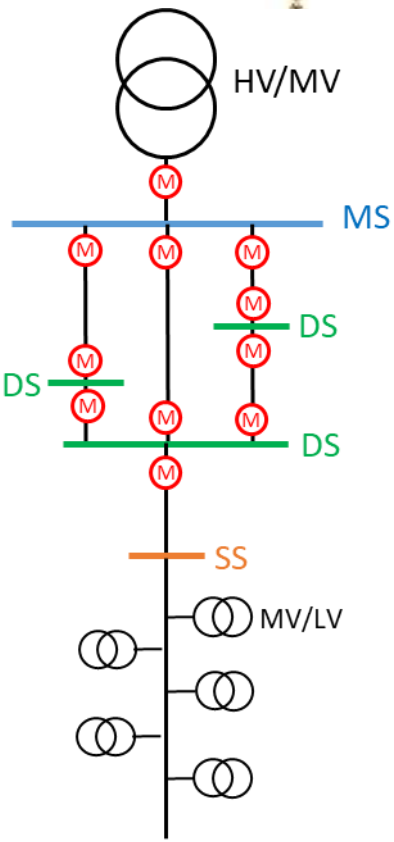
3. Model included LV kiosks
4. Load and generation lumped at LV kiosk

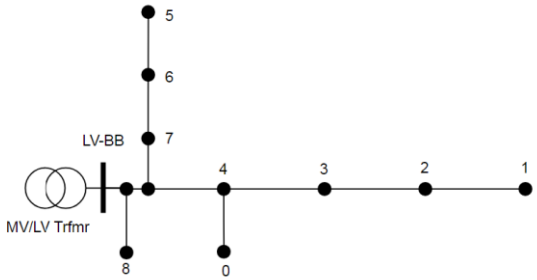


5. Property is allocated to the nearest LV kiosk
6. Connections are distributed across phases

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.





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.

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).

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

Simulation Methodology (1)

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

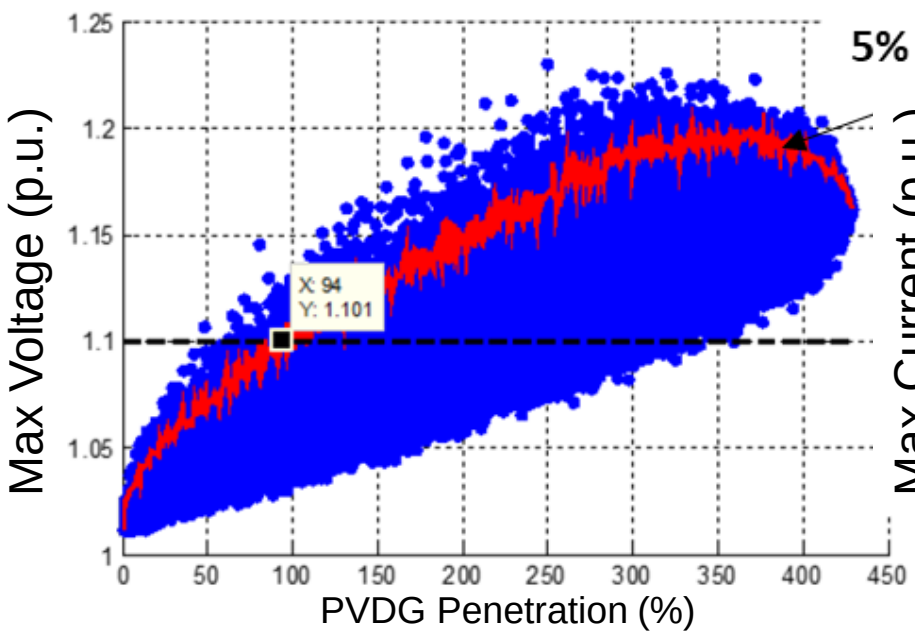
Feeder MD : Maximum load the feeder can supply before network violations

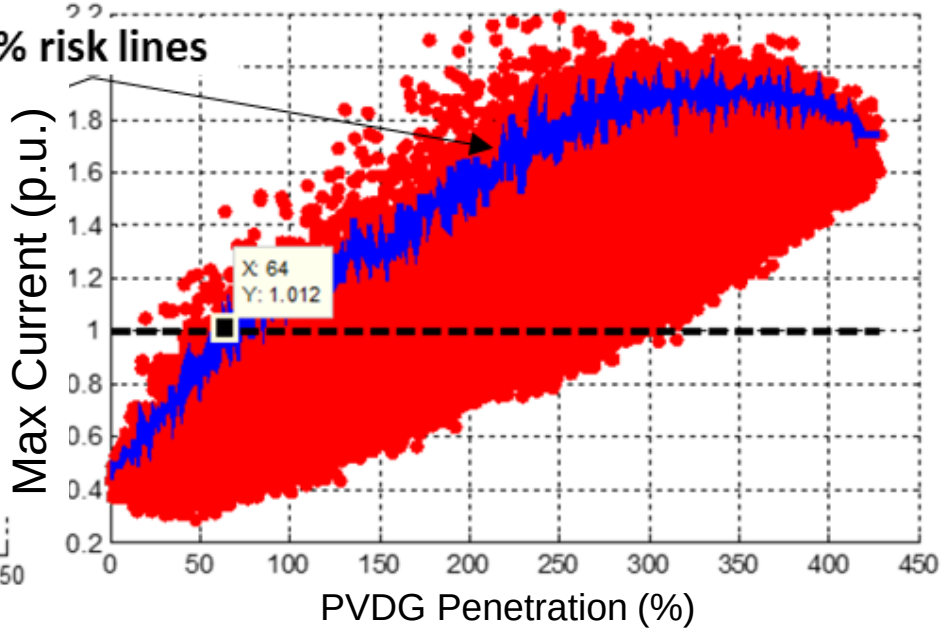
Simulation Methodology (2)

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

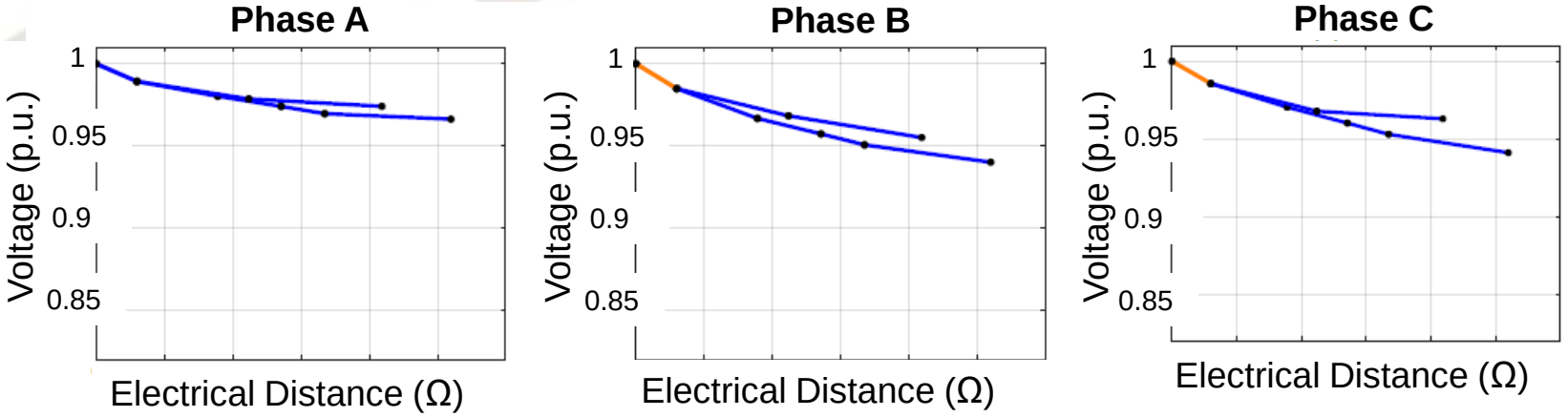
Results


Max Voltage (p.u.)
1.25
1.2
1.15
1.1
1.05
1
X: 94
Y: 1.101
0
50
100
150
200
250
300
350
400
450
PVDG Penetration (%)

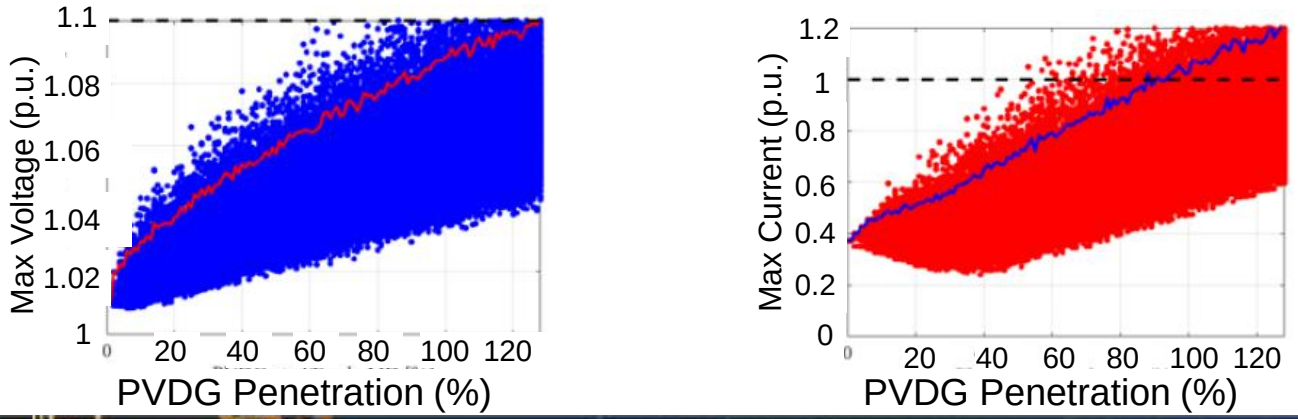

5% risk lines
Max Current (p.u.)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
X: 64
Y: 1.012
0
50
100
150
200
250
300
350
400
450
PVDG Penetration (%)

Results – Highest PV penetration

Passive feeder:

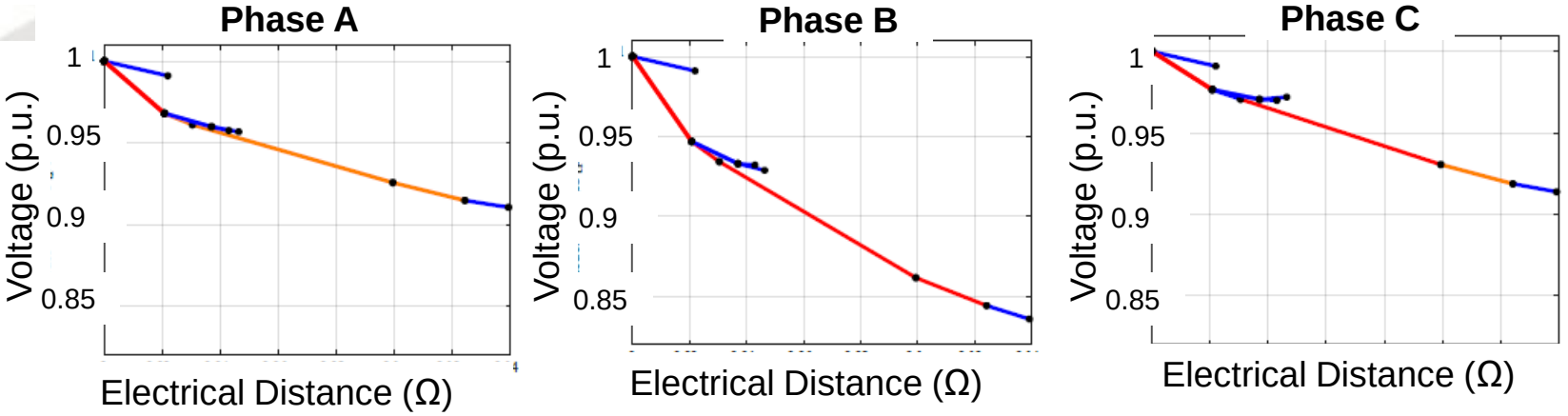


Active feeder:

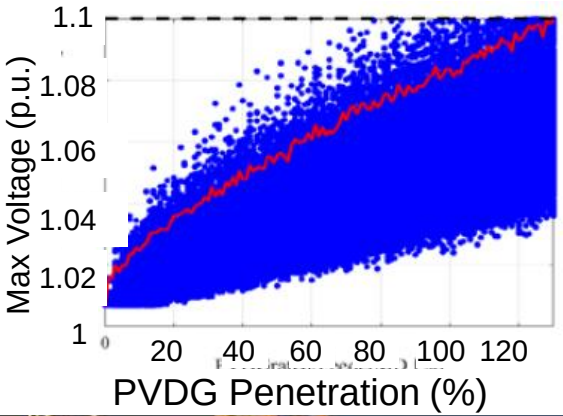


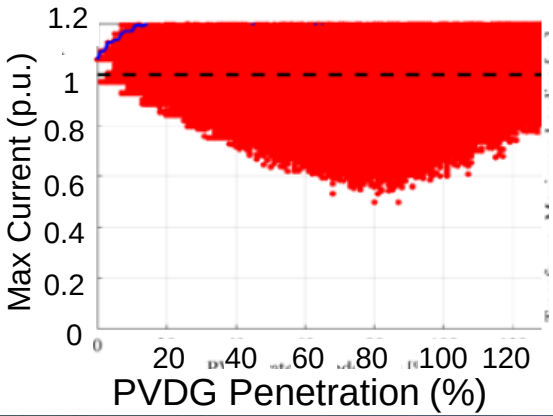
Results – Lowest PV penetration

Passive feeder:



Active feeder:





Conclusions – Benefits

- A methodology was developed
- Better understanding of PVDG problems

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 ±7kWp/hh
  - Penetration limit increases if PVDG is limited per household
  - Balanced networks can accommodate more PV than unbalanced networks

Conclusions – Way forward

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

Acknowledgement

- Co-authors & workgroup members:
  - CT Gaunt – University of Cape Town,
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  - N Mararakanye - Stellenbosch University
  - M Tsholoba – City of Cape Town

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