Eskom

LV Embedded Generation Hosting Capacity

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Powering your world

Overview

- Background
- Grid Code and NRS documents
- HBM modification
- Scenarios tested
- Results
- Conclusions
- Recommendations

Background

- Grid connection code for renewable power plants (RPPs) connected to the electricity transmission system (TS) or the distribution system (DS) in South Africa (RPP grid code)
  - Category A: 0 < S < 1 MVA (LV connected only)
    - A1: 0 < S ≤ 13.8 kVA
    - A2: 13.8 kVA < S < 100 kVA
    - A3: 100 kVA ≤ S < 1 MVA

    NOTE: S > 4.6 kVA must be balanced three-phase
  - Category B: 1 MVA < S < 20 MVA
  - Category C: S ≥ 20 MVA

Background

- Connection rules, technical requirements etc. fairly well defined for RPPs in categories B and C
  - Planning and quotation phases
  - Grid Code compliance simulations and testing
  - Contracts:
    - Connection Agreement
    - Power Purchase Agreement
    - Operational Agreement
  - Eskom connection requirements
- Category A gaps partially covered by NRS 097-2-1 (Ed1)
  - Edition 2 intends to close some of the gaps (and in line with RPP GC)

Category A challenges

- Connected to LV
  - Rule-of-Thumb < 1 MVA (NRS097-2-1 and RPP GC)
- Planning / design phase for each application?
  - Combined impact on network / other installations?
- Control of each installation?
  - SCADA?
  - Forecasting?
- Safety of installation
  - Customer installation safety
  - Utility personnel

Category A (continued)

- NRS 097-2 series of documents:
- NRS 097-2-1: Utility interface (Ed2 in preparation)
- NRS 097-2-2: Type testing (in preparation)
- NRS 097-2-3: Simplified utility connection criteria for LV connected generators
    - Flow-chart with simplified acceptance criteria
    - LV connection length related to voltage rise
    - Meet NRS 097-2-1 technical requirements
- Research to inform the simplified acceptance criteria as well as more detailed studies for more “complex” applications

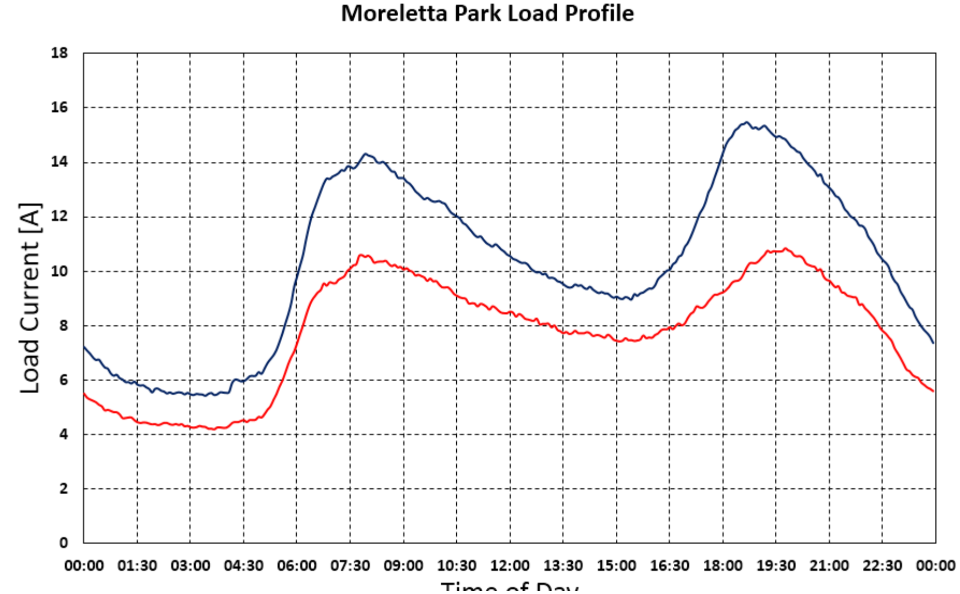
UCT Research on Hosting Capacity

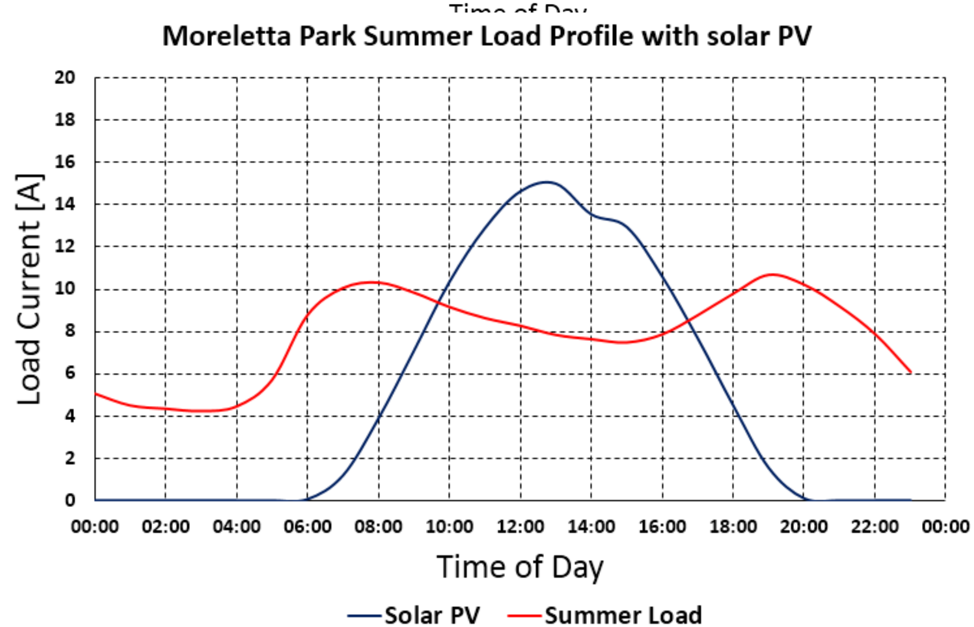
- Prof Trevor Gaunt, Dr Ron Herman and Emmanuel Namanya
- Evaluate the hosting capacity of LV feeders based on load and generation patterns
- Focus
  - SSEG (connected to LV)
  - Voltage rise – steady state variations
  - PV with inverter
  - High-income customers (LSM7-8)
- Modified Herman-Beta algorithm to include varying generation along with varying loads

Scenarios Selection

- Characteristic load profiles
  - LSM 7-8
  - Variation of load and generation
  - Single-phase vs. three-phase
  - Solar Water Heating

    (Excluded in first phase)





Scenarios Selection

- Characteristic Topology
  - Linear or branched feeder
    - Loss of diversity on branches
  - Range of number of customers
    - 6 – 40 customers per feeder
  - Customers per node
    - Clustered from 1 customer per kiosk up to 6 customers per kiosk
  - PV Connections
    - No constraint on position
    - Can be three-phase
    - Limited to 60A per node

Scenarios Selection

- Characteristic Embedded Generation
  - Maximum size of PV
    - Current limit of 25% of size of connection, e.g. 15A for 60A breaker capacity
    - Research to be expanded to 50% of connection size
  - Daily variation of PV output
    - As per rating of PV installation
  - Orientation and shadowing
    - Actual installation
    - Assume perfect installation with no shadowing (i.e. maximum)
  - Generators modelled as negative loads
    - Similar to loads in HBM – use current to characterize the generator

Scenarios Selection

- Constraints
  - PV installations only
  - Source voltage at nominal
  - Passive feeders: assume maximum of 10% voltage drop for maximum load
  - With PV generation -> maximum of 10% voltage rise at any node
  - No reverse power flow allowed to MV network
  - 10% risk (90% confidence) levels selected

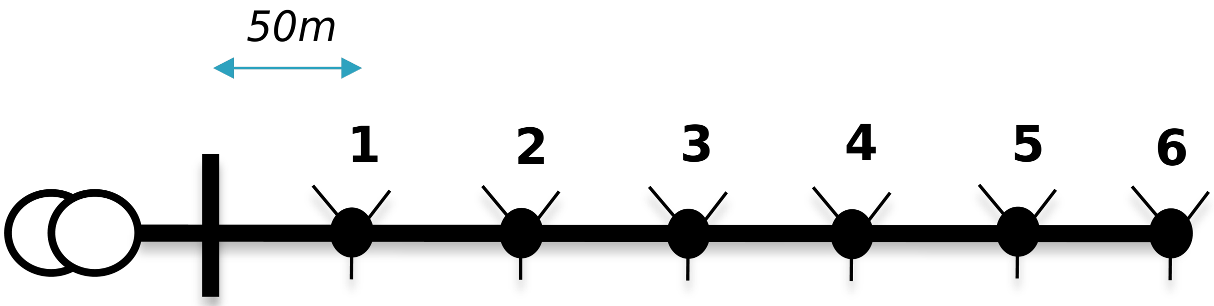
NOTES:

1. Source voltage usually above nominal

2. European standards typically allow 3% voltage rise on a feeder due to EG

Scenarios Chosen

- CASE 1 (Base case)
  - Load: High LSM, single-phase load profiles (seasonal high and low)
  - Number of customers: 18 (3 per node)
  - PV: Single-phase, 1 kW, randomly distributed on nodes & phases
  - Increments of 1kW with any number of units assigned to any node using Monte Carlo with H-B (DG)
  - Results to be used as guide to further variations



Further Variations

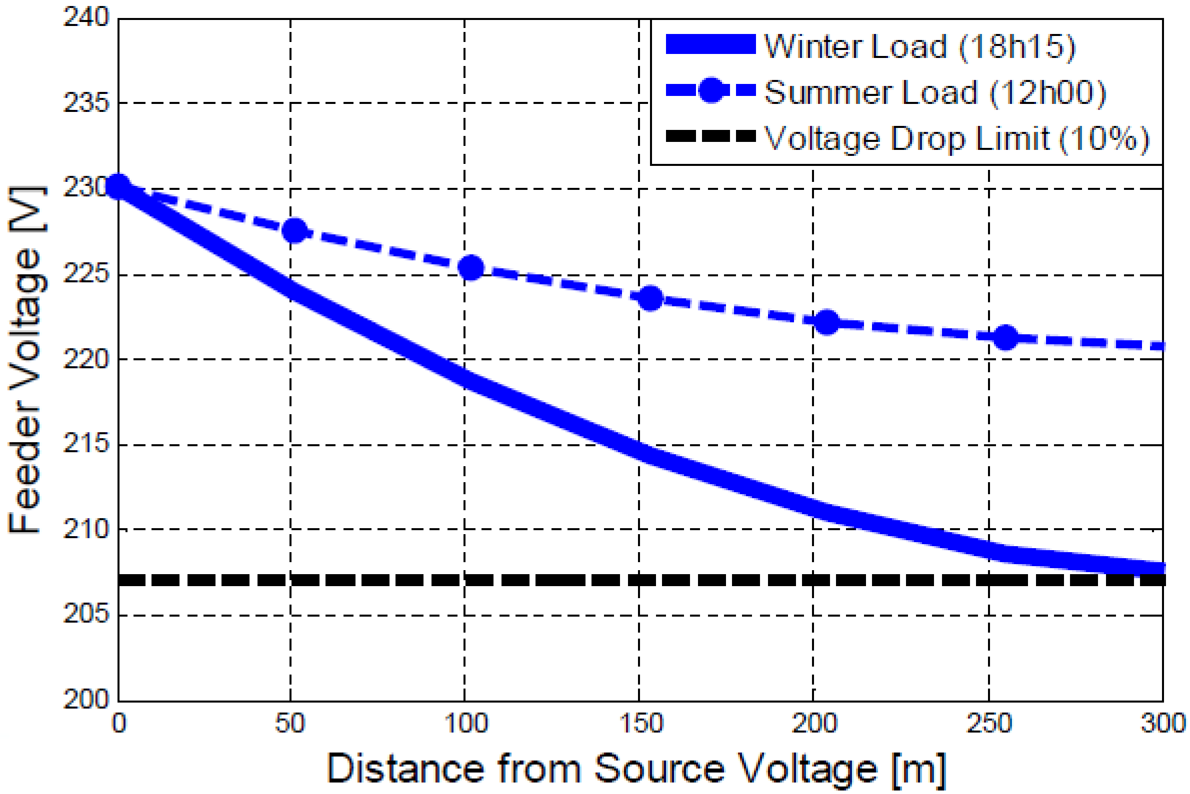
- As in Case 1 but with lumped 3.5kW single-phase PV
- As in Case 1 but with lumped 10kW three-phase units
- As in Case 1 but with branch of 2 nodes at node 2
    - Lumping near source
- As in Case 1 but with an increased source voltage

Voltage Constraint

- Design for maximum voltage drop using winter load
- The parameters of the load model are:
  - Winter peak load used to size the conductor: a=1.09; b=2.22; c=61.48 A; admd=4.657 kW; Vs=230 V; resultant voltage drop = 10%.
  - Load for maximum difference between PV profile and load profile, at 13:15 in summer: a=0.628; b=1.233; c=22.602 A; admd=1.76 kW; Vs=230 V
  - The parameters of the 1 kW PV module are:
  - a=255; b=255, c=8.696 A
  - (Note: The large a and b parameters represent a virtually fixed load or source with negligible dispersion and with mean current of half the value of c.)

Voltage Constraint

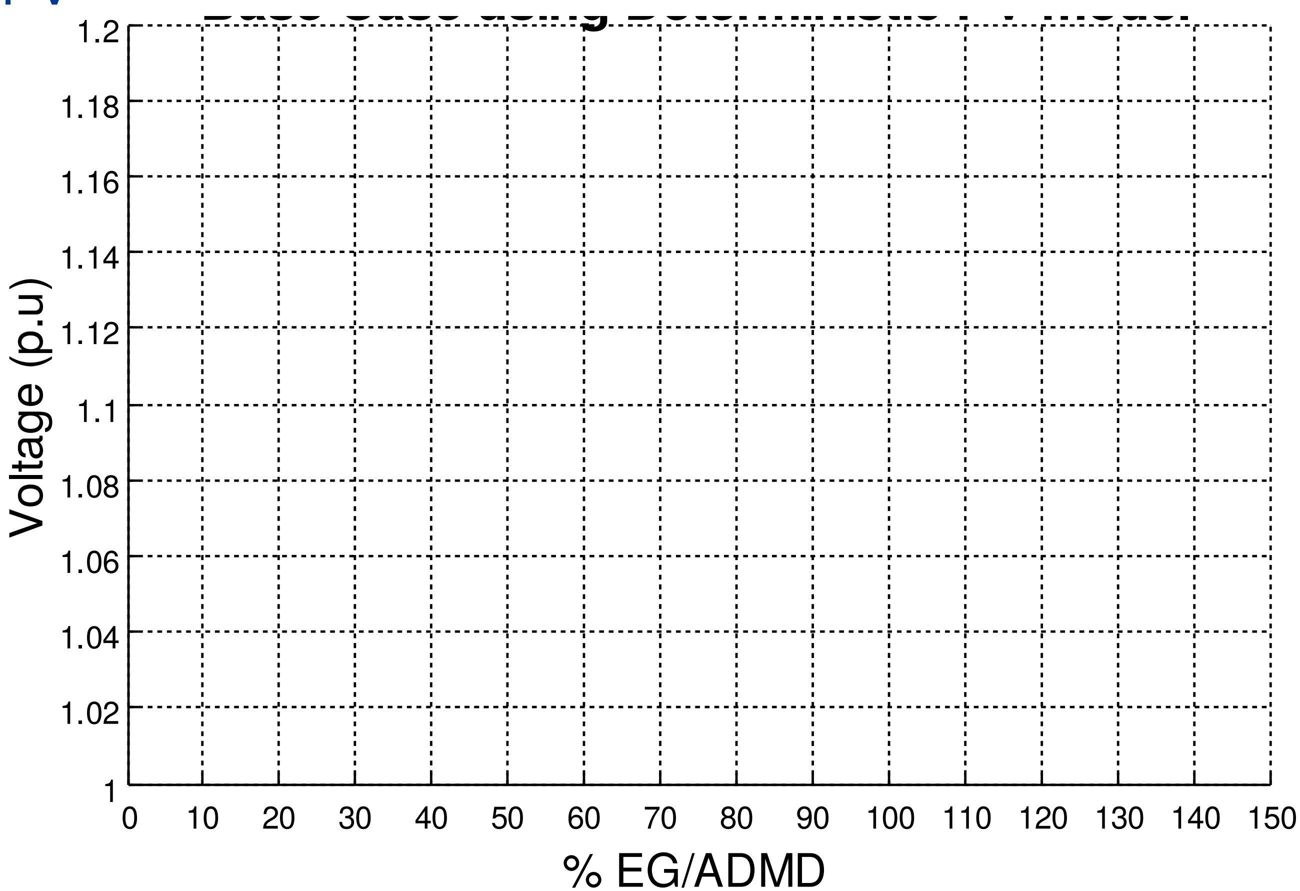
- Design feeder for maximum voltage drop using winter load



Case 1: Max Feeder Voltage Scatter Plot

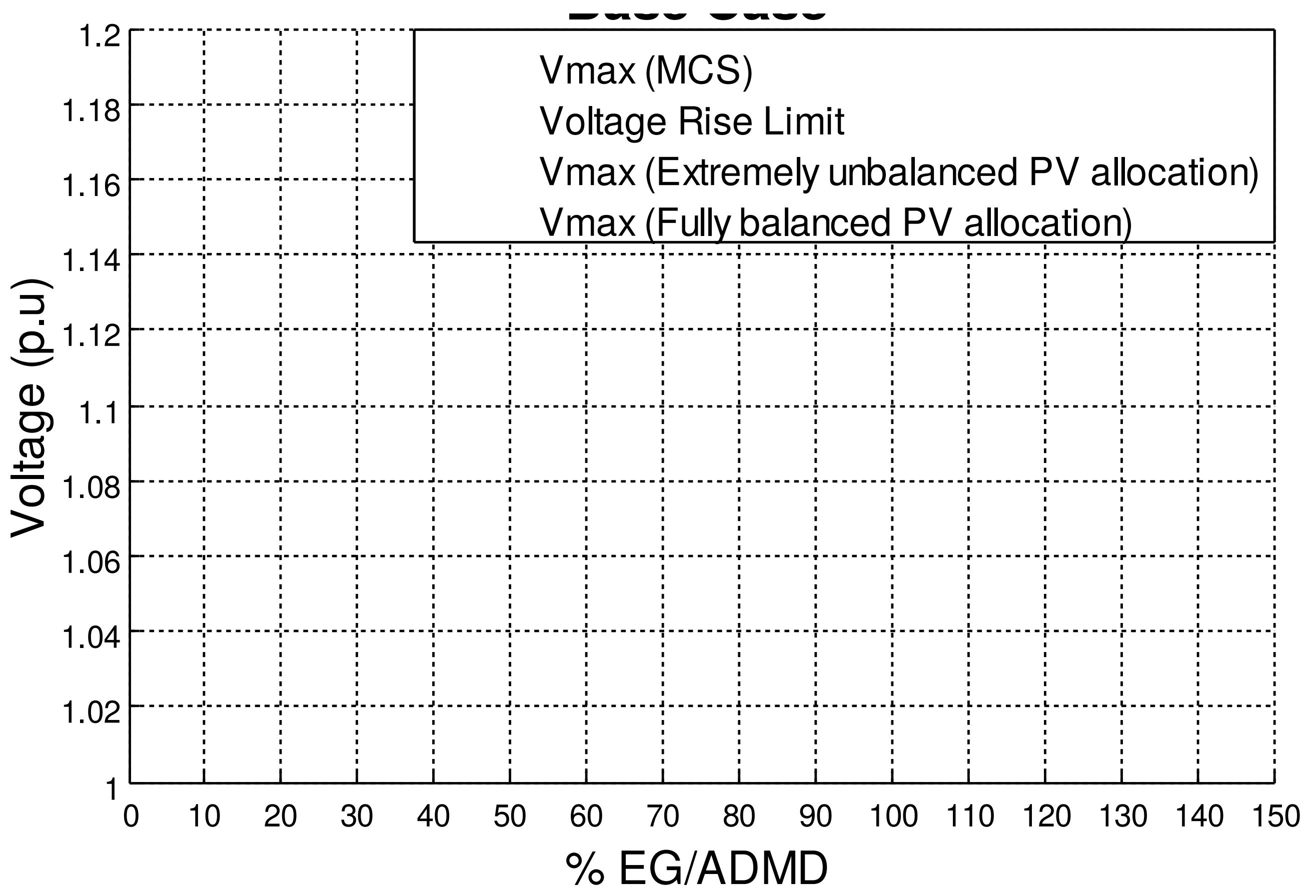
- Maximum difference between load and generation found at 13:15 (summer load)

- 1kW PV



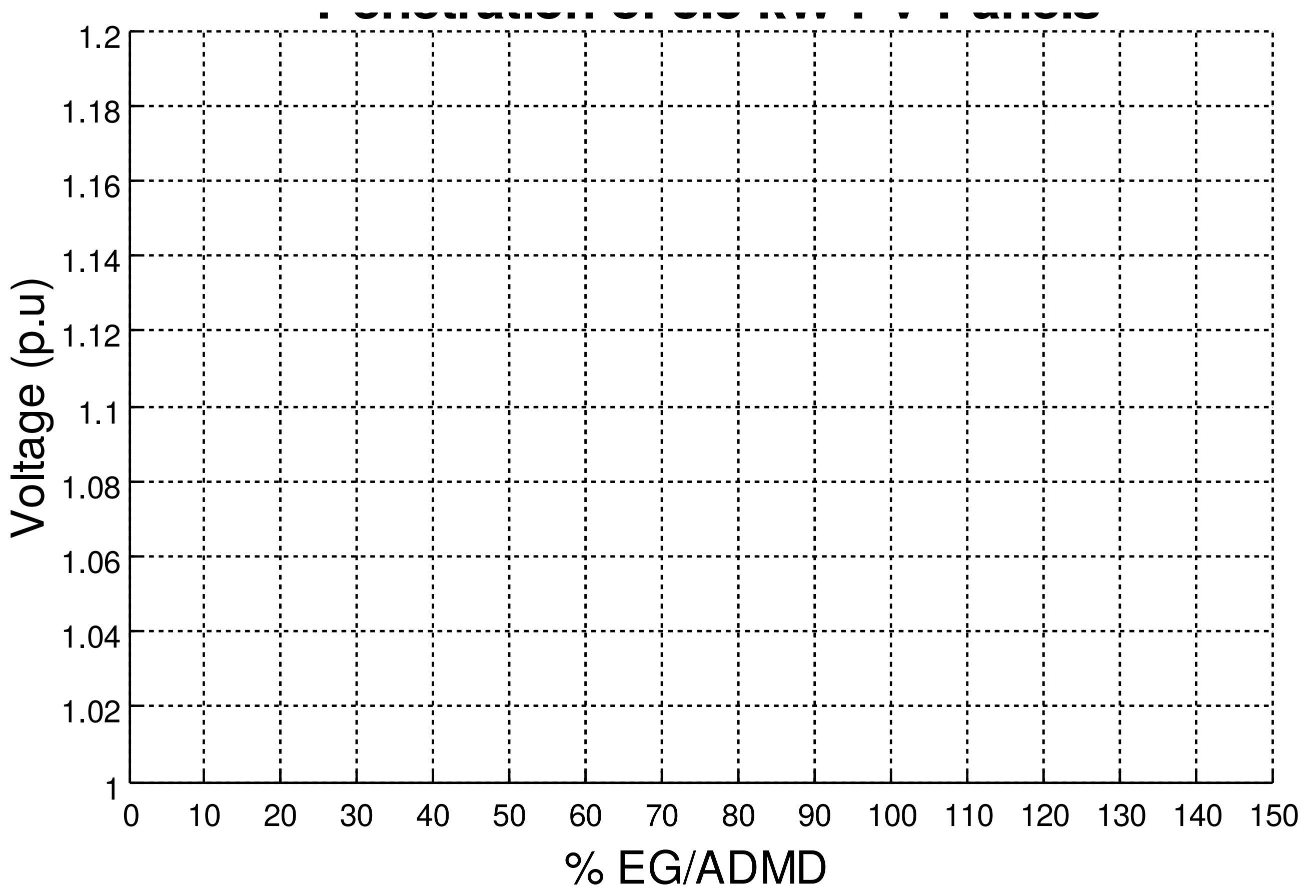
Case 1: Max Feeder Voltage Scatter Plot (2)

- Simulating extremes… create envelope



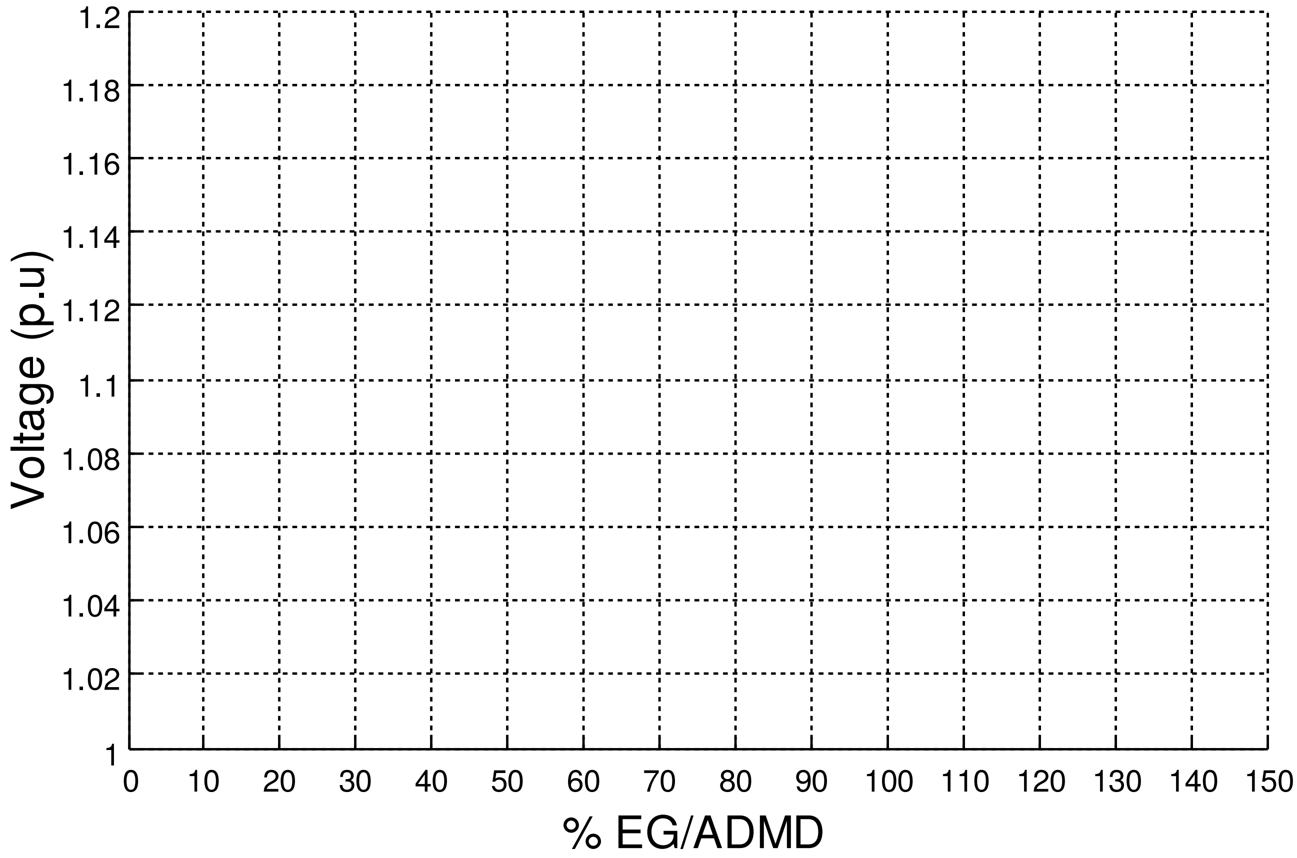
Case 2: Max Feeder Voltage Scatter Plot

- 3.5kW single-phase generators

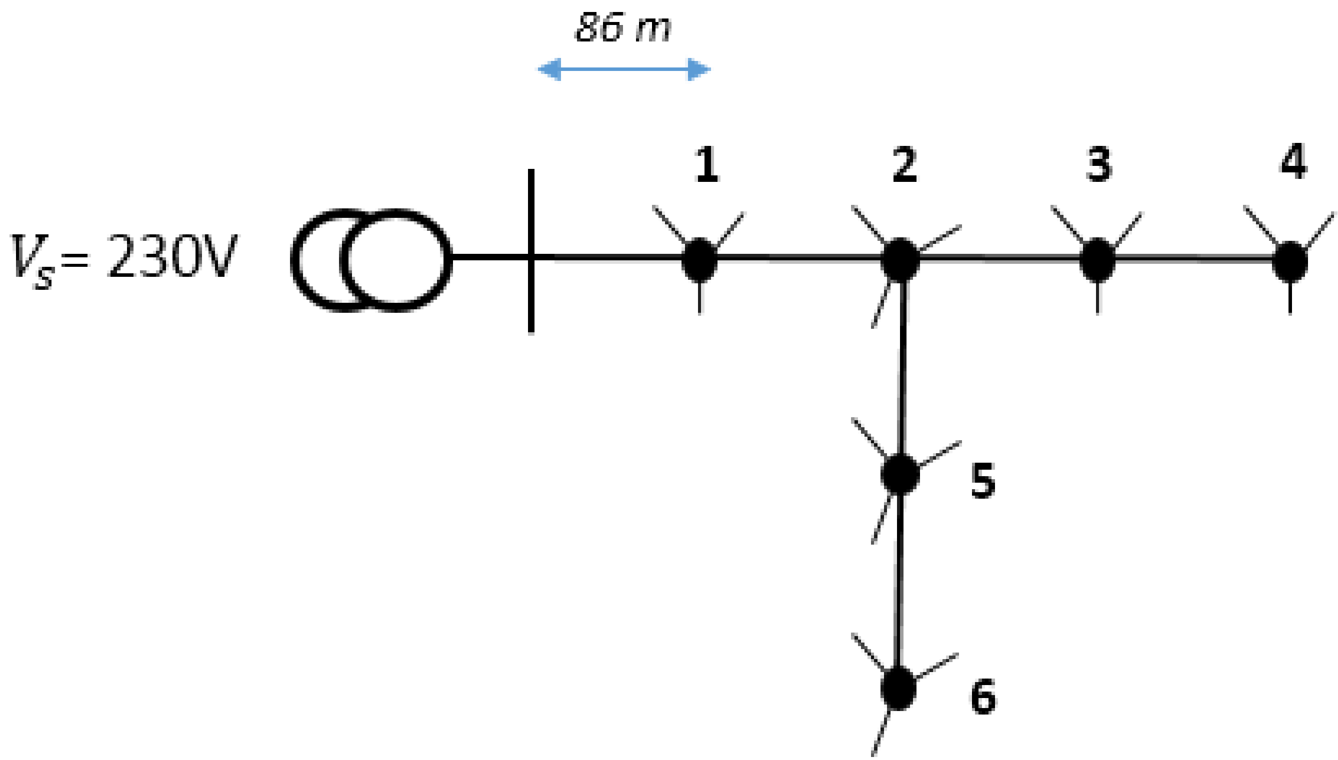


Case 3: Max Feeder Voltage Scatter Plot

- 10kW three-phase generators

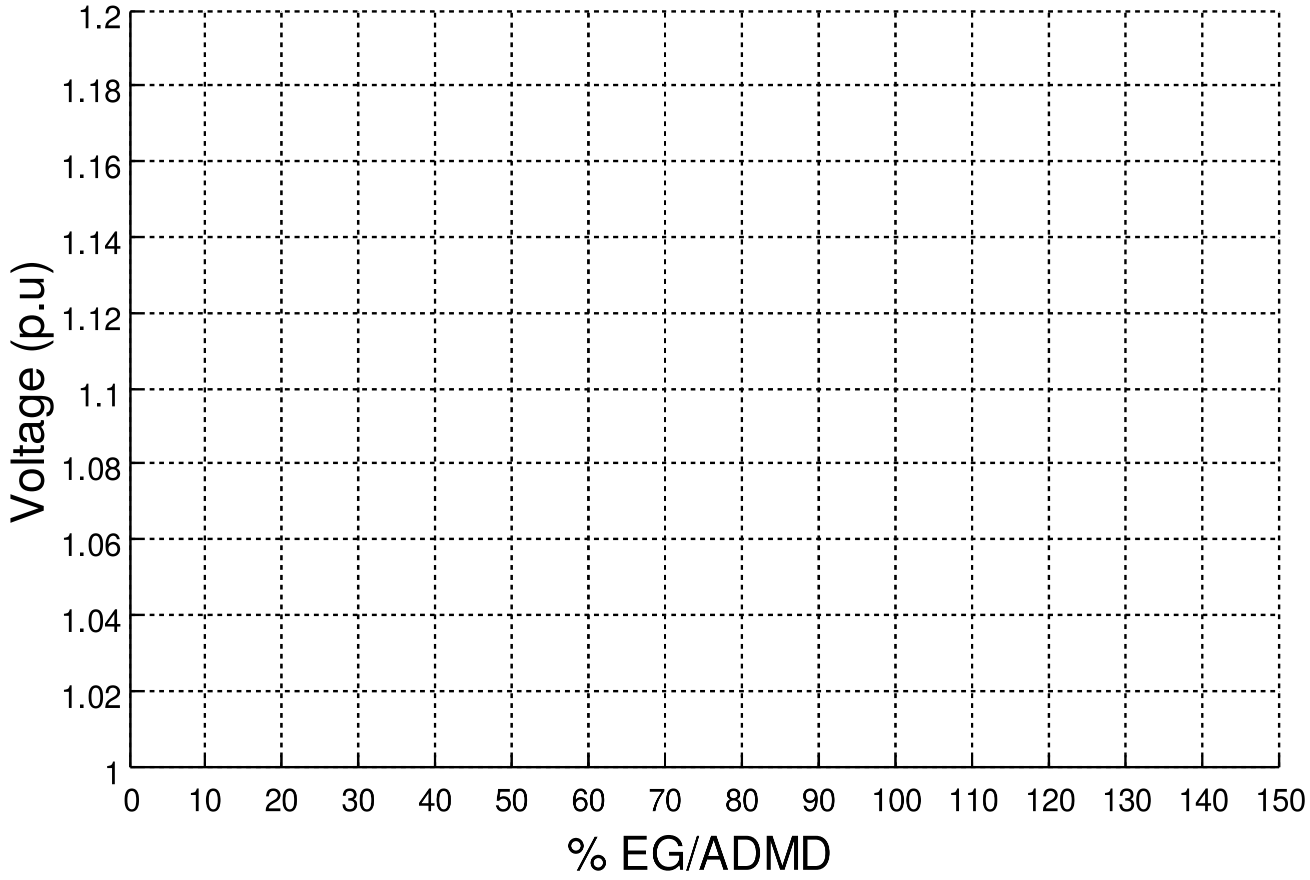


Case 4: Branched Feeder at Node 2



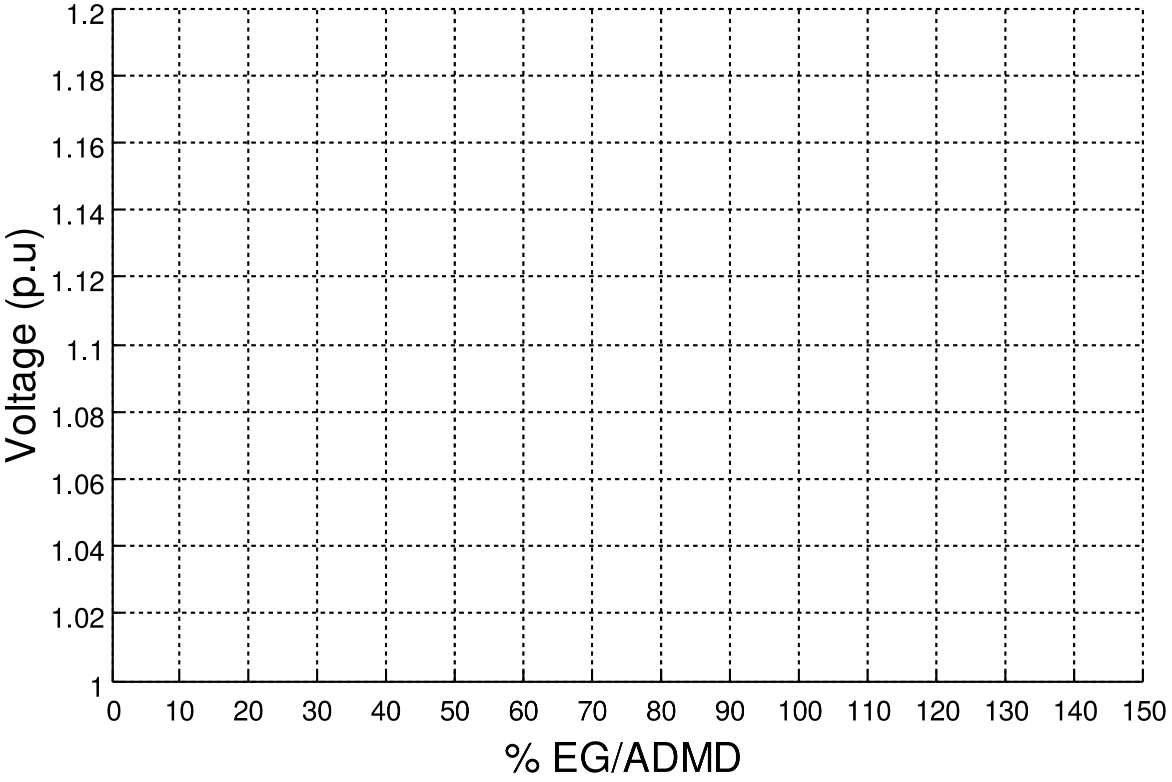
Case 4: Max Feeder Voltage Scatter Plot

- 1kW single-phase generators



Case 5: Max Feeder Voltage Scatter Plot

- 1kW single-phase generators
- Increased source voltage



Conclusions

- The modified Herman Beta method is a powerful tool to analyse the impact of generators on LV voltage regulation
- Approximately 30-35% penetration of design load demand can be tolerated:
  - Allowing for an elevated source voltage
  - Risk level of 10%
- Compares favourably with the 25% of customer demand (breaker size) limit contained in NRS097-2-3
- Three-phase EG allows for a larger penetration percentage

Final comments

- Aspects not yet researched:
  - Thermal loading of LV conductors/cables
  - Effect of reverse power flow into MV network
  - Further LV feeder configurations
  - Control modes for PVEG (support for network voltage)
  - Correlation of solar water heating and PVEG
  - Impact of LV network unbalance on hosting capacity (link to proposed penetration limits)
  - Quality of Supply impacts, e.g. voltage variations (flicker) and harmonics

Thank you