Parameterization of Aggregated Distributed Energy Resources (DER_A) Model for Transmission Planning Studies

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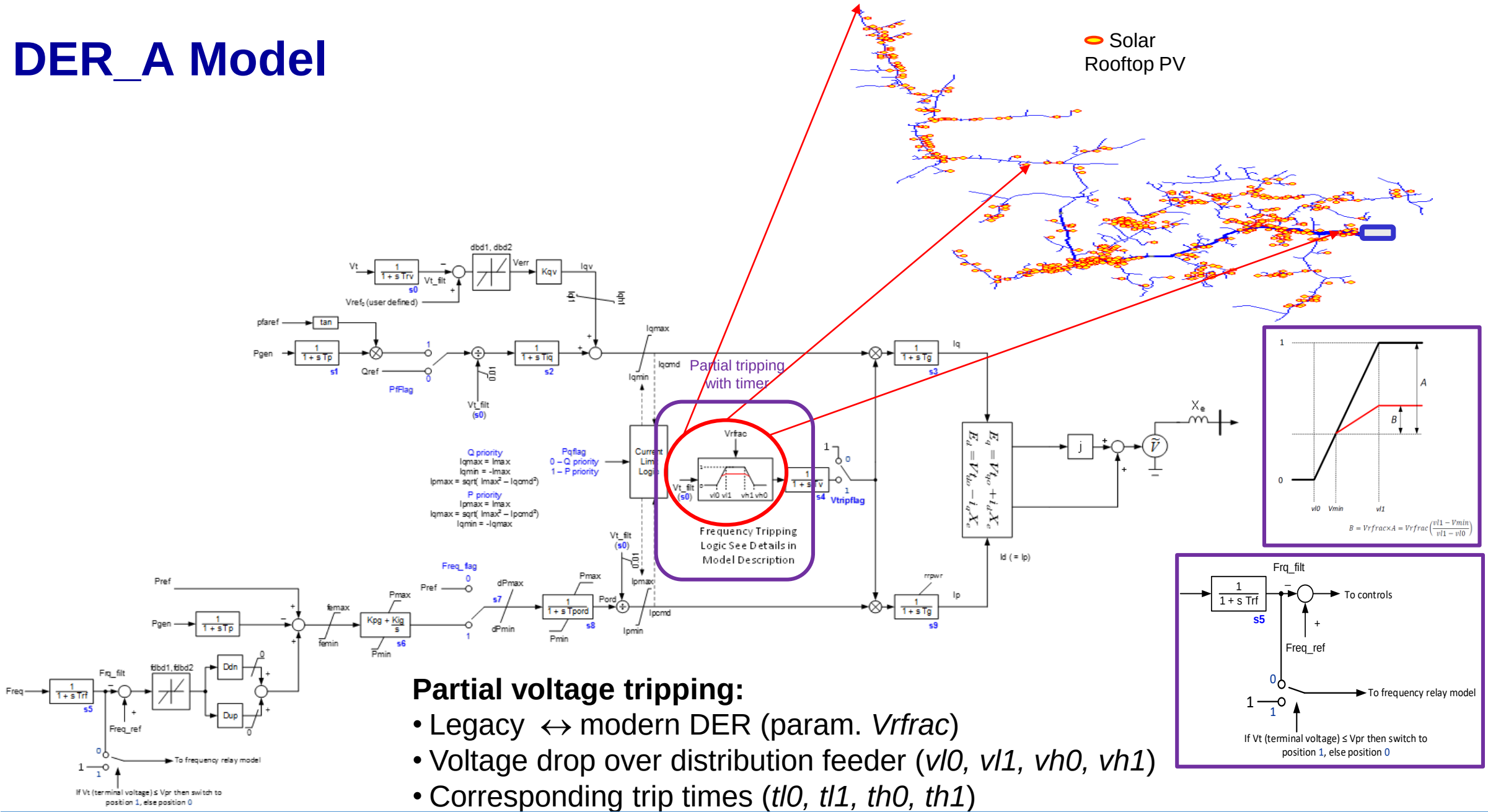
DER_A Model



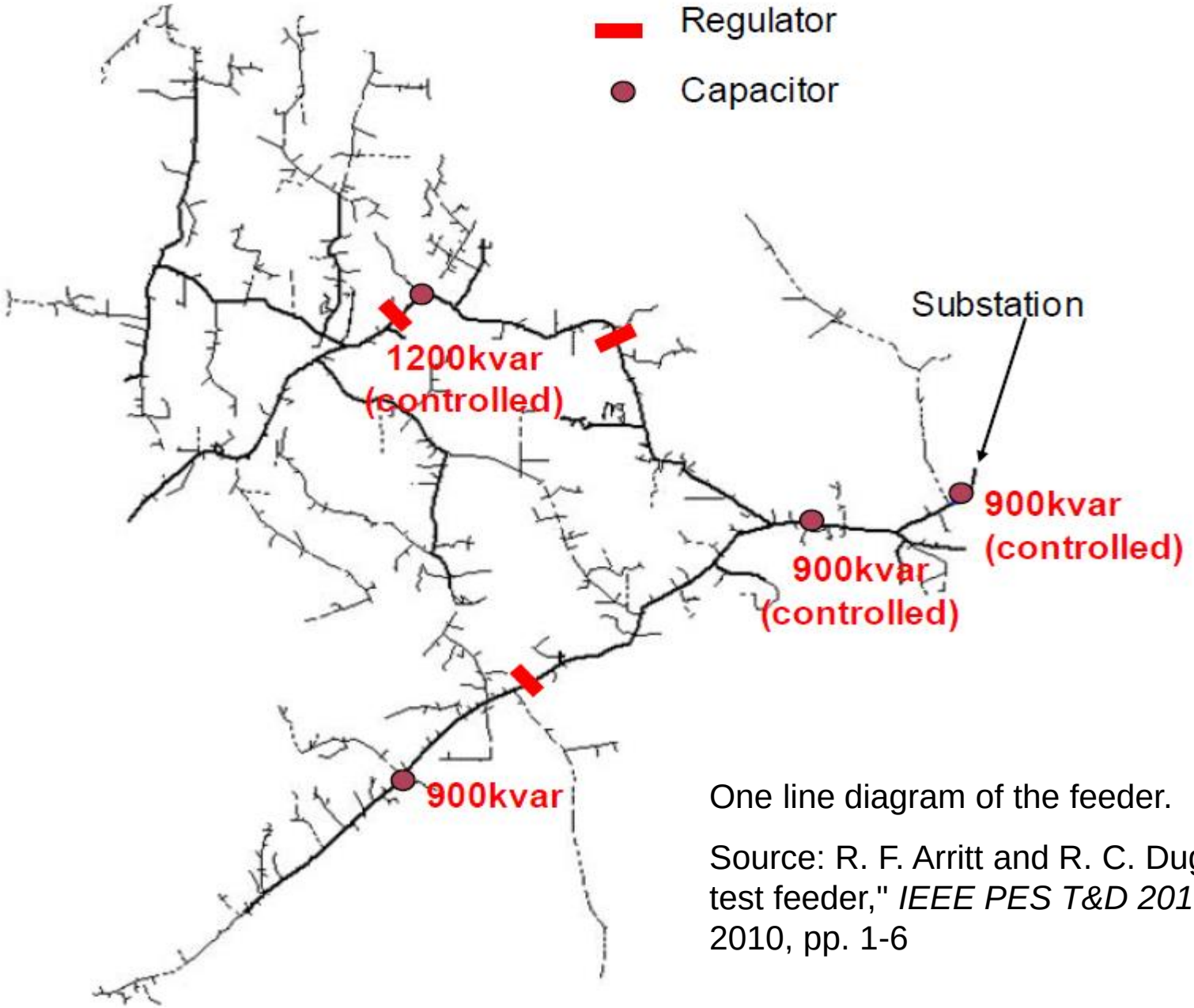
Partial voltage tripping:

- Legacy ↔ modern DER (param. *Vrfrac*)
- Voltage drop over distribution feeder (*vl0, vl1, vh0, vh1*)
- Corresponding trip times (*tl0, tl1, th0, th1*)

How to find parameter values for the model? Current focus is on voltage thresholds.

Approach

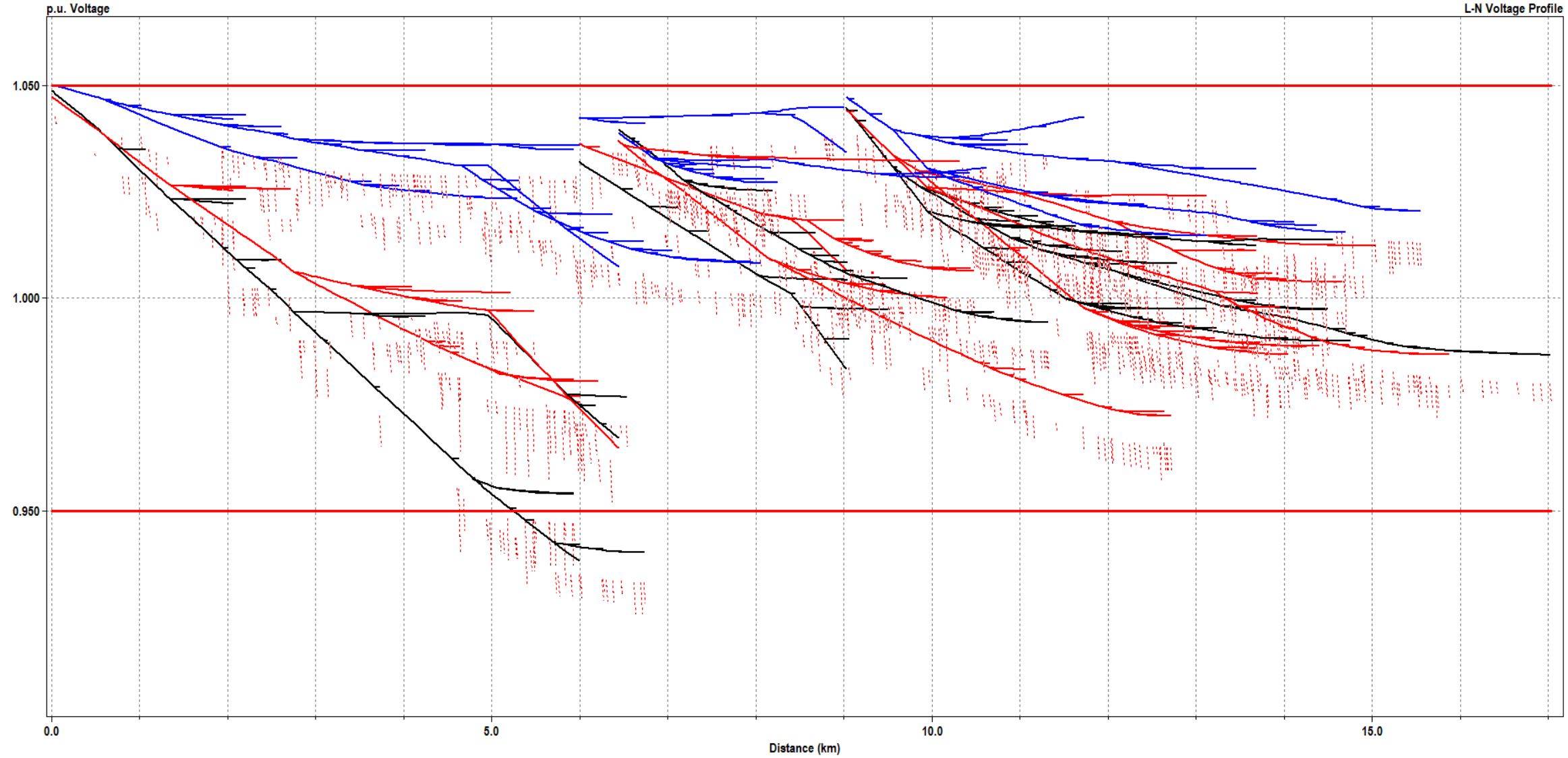
- Develop detailed distribution feeder model in OpenDSS (http://smartgrid.epri.com/SimulationTool.aspx)
  - Inverter location, size, trip characteristics are modeled from the actual information available.
- Perform simulations
  - Apply sags at the substation with different magnitudes
  - Sensitivity analysis: stochastic variation in terms of location, and type of inverters (legacy vs. new, size, trip settings etc.)
- Find *vl0, vl1, vh0, vh1* based on the simulations
- Potentially repeat the analysis for different feeders types (mostly residential, residential-commercial mix etc.)



One line diagram of the feeder.

Source: R. F. Arritt and R. C. Dugan, "The IEEE 8500-node test feeder," *IEEE PES T&D 2010*, New Orleans, LA, USA, 2010, pp. 1-6

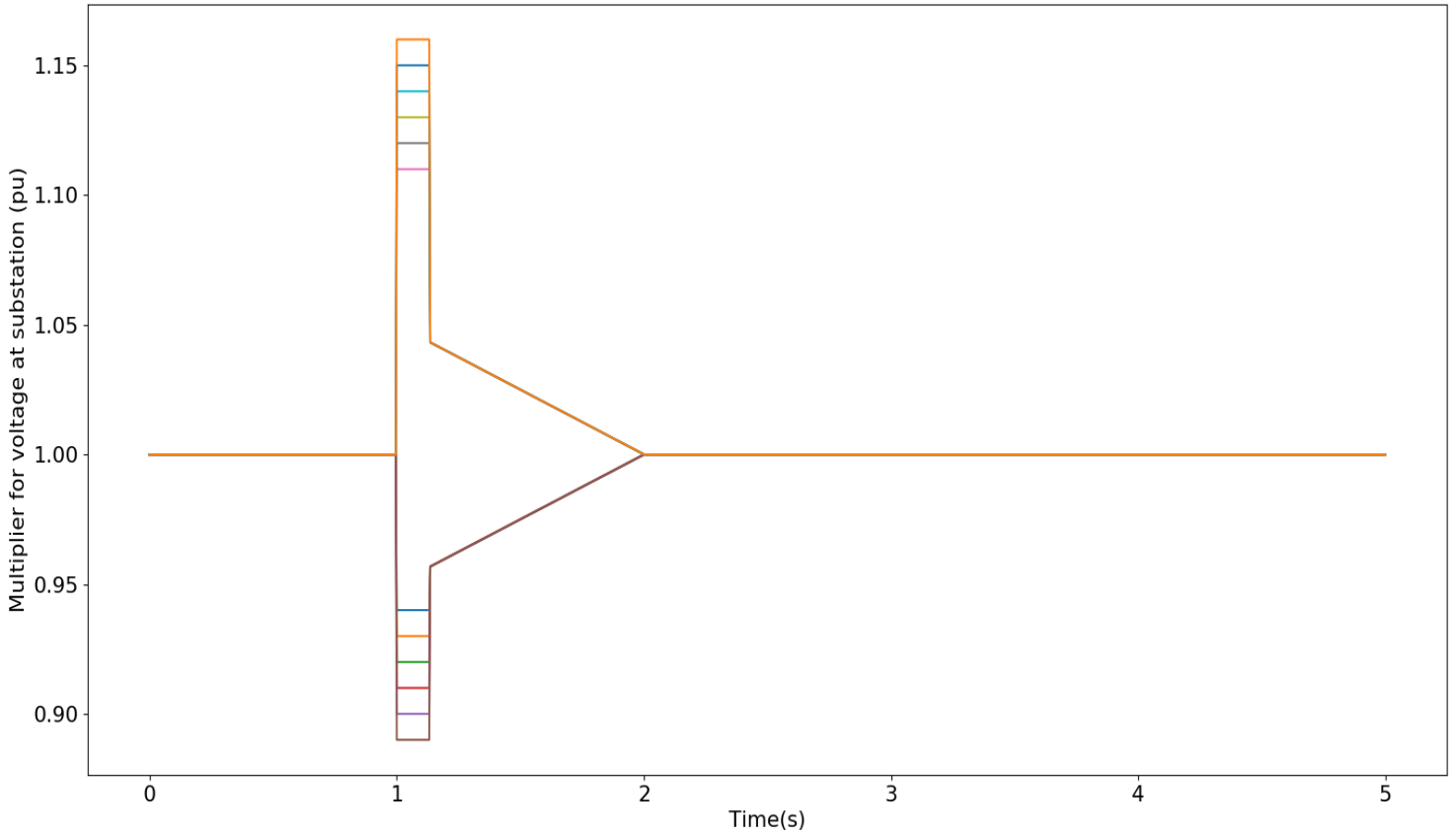
Line to neutral voltage profile of 8500 node feeder without any additional inverters and balanced loads



Individual Legacy Inverter Description

- Group A (residential R-DER)
  - P = 15kW
  - S = 15kVA
  - Under voltage trip = 0.88pu for 0.1s
- Group B (commercial R-DER)
  - P = 35kW
  - S = 35kVA
  - Under voltage trip = 0.5pu for 0.1s
- Both are 3-phase, roughly based on IEEE 1547-2003
  - **Only legacy inverters in the present analysis**

Play-in Voltage Sags/Swells Simulations



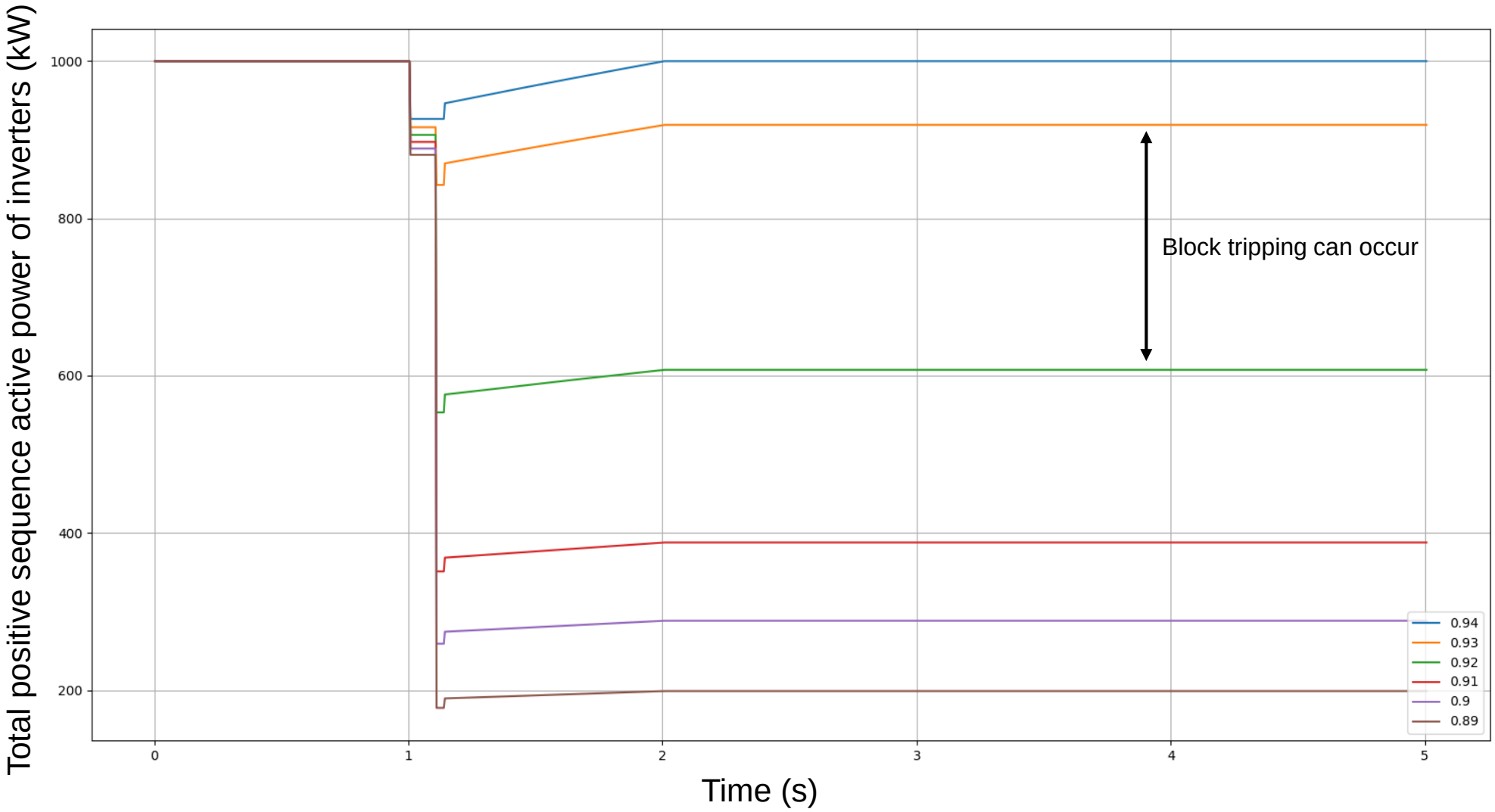
Group A Vsag = [0.94, 0.93, 0.92, 0.91, 0.9, 0.89]
Group B Vsag = [0.5, 0.49, 0.48, 0.47, 0.46, 0.45]
Vswell = [1.11,1.12,1.13,1.14,1.15,1.16]

For each sag/swell level

Load 8500 Node Model with DERs
Solve powerflow
Enable relays
Set dynamics mode: 0-5s in 4ms increments
Set Vsource = Vsag/Vswell
Solve (integrate equations) one time step at a time
Store remaining power at 5s

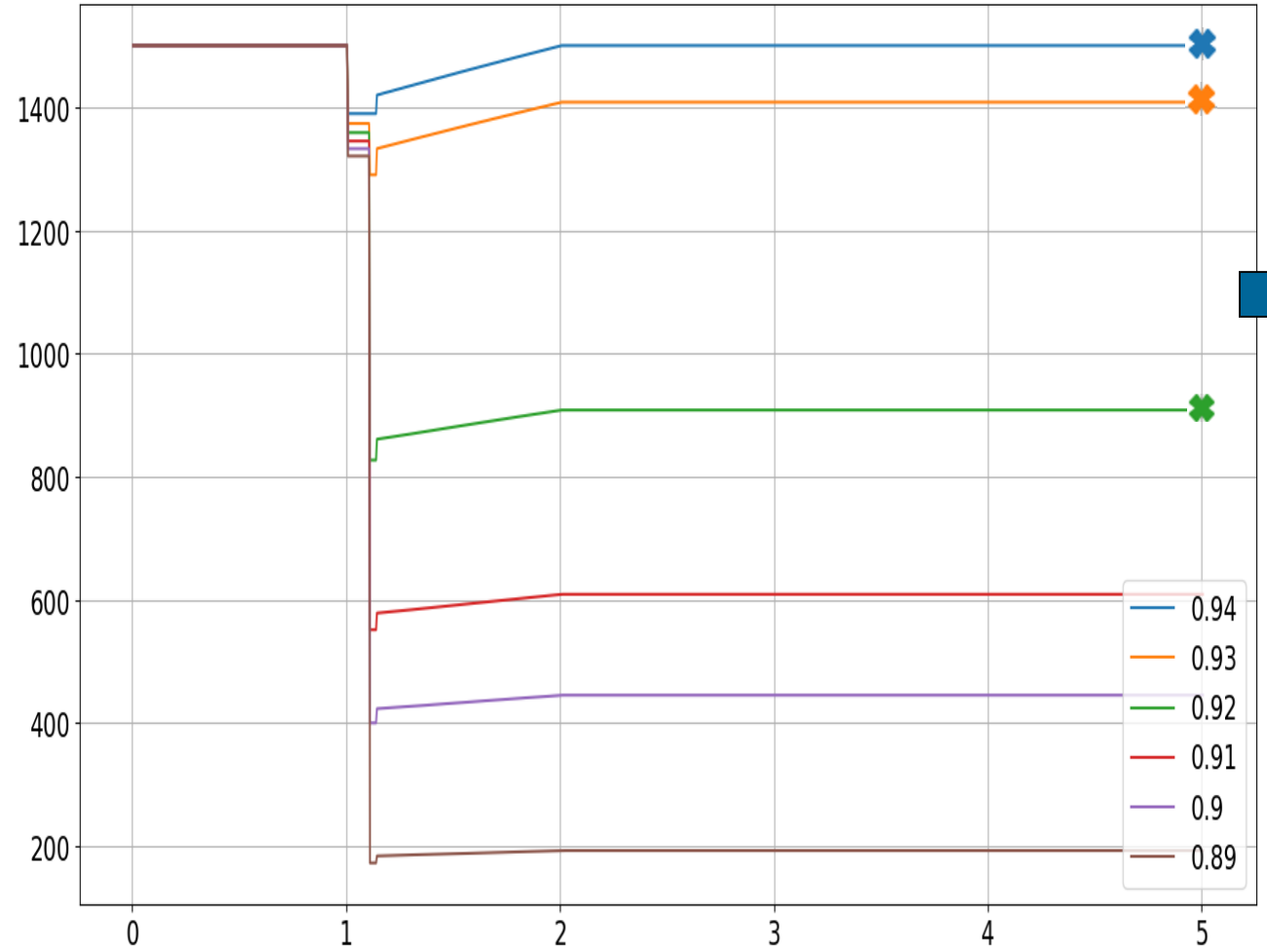
Done

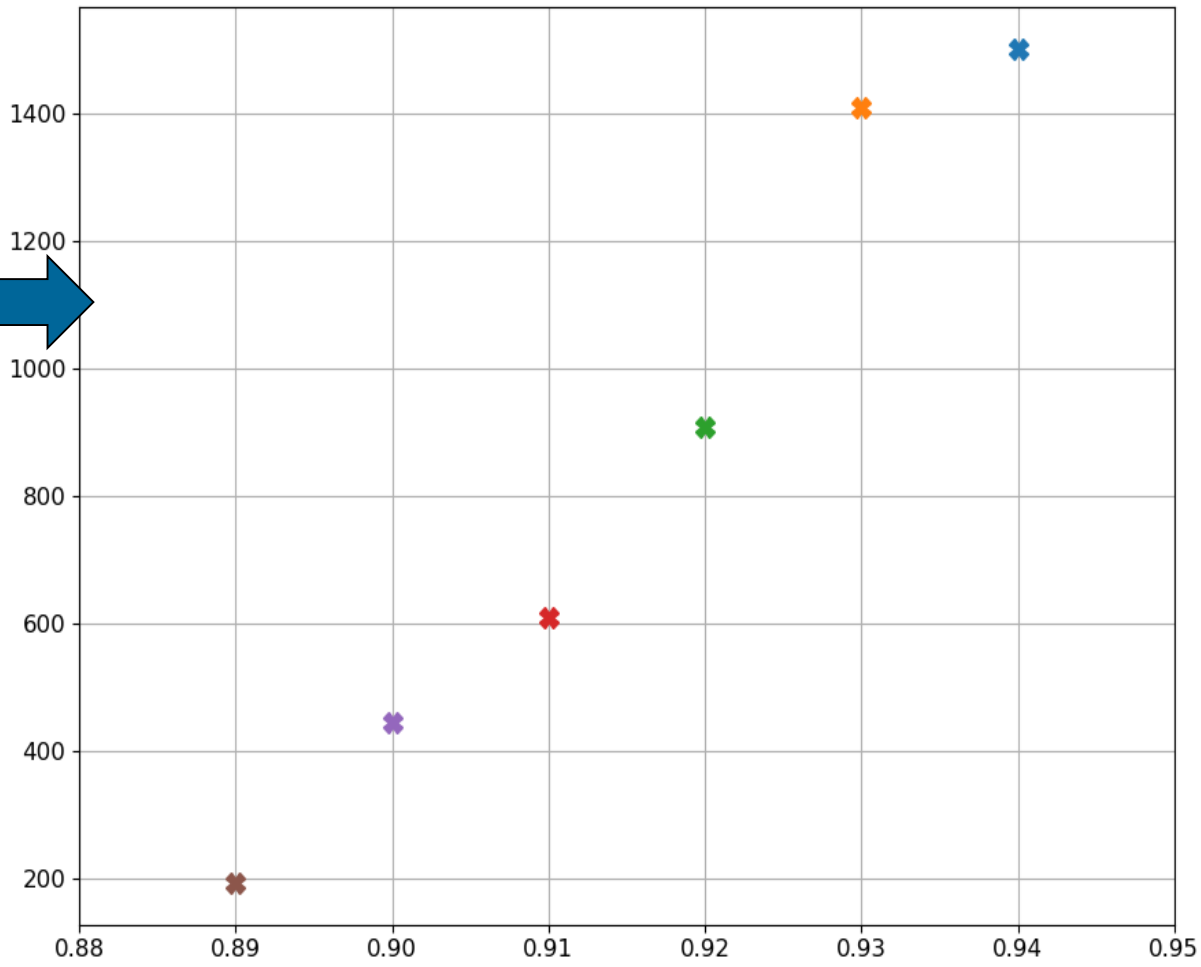
Only Group A inverters – Single location set, 6 sag depths



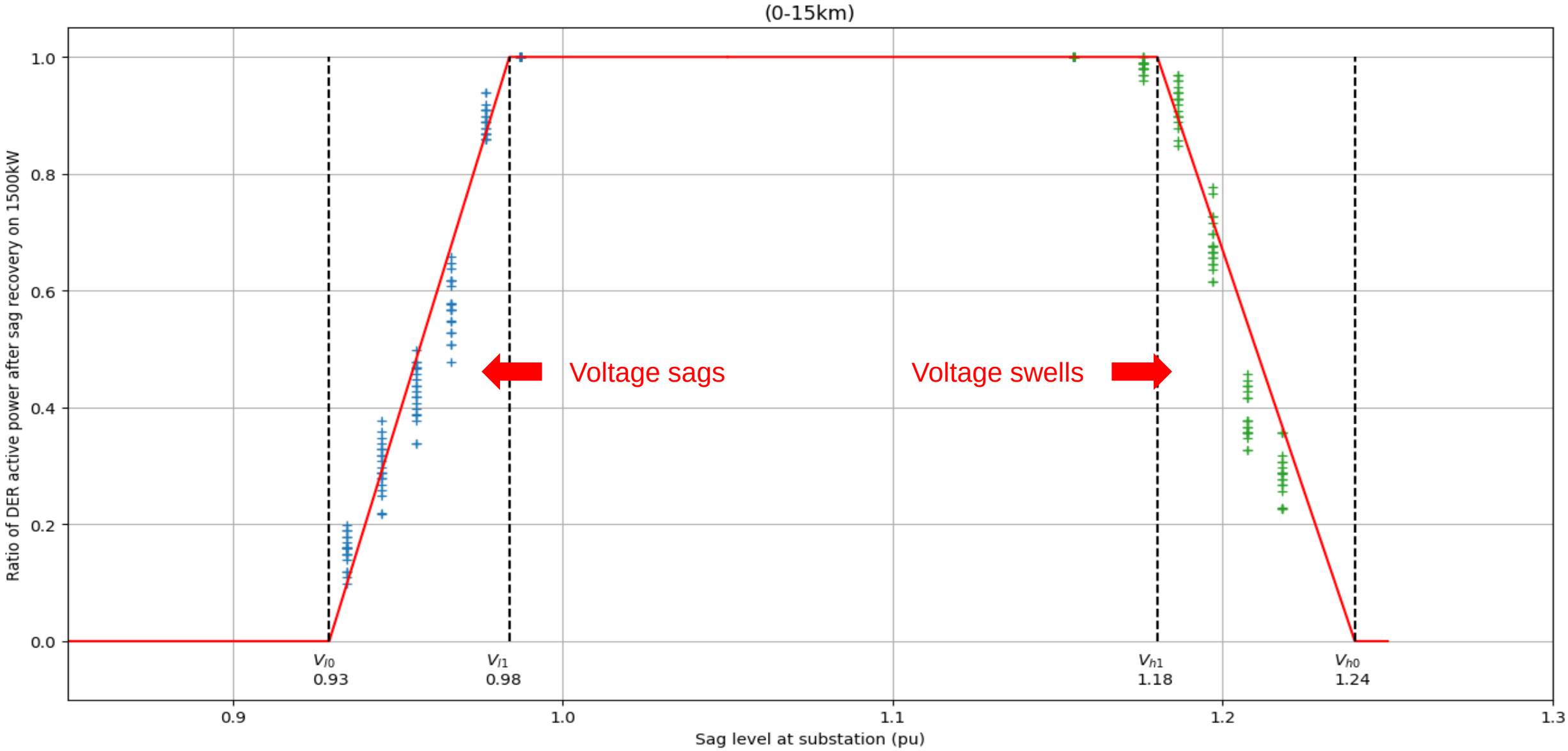
- Each indicated sag depth is multiplied by initial substation voltage for actual depth.
- Represents a simulation carried out with 100 DERs each of 10kW

Translation to an Under Voltage Trip Characteristic

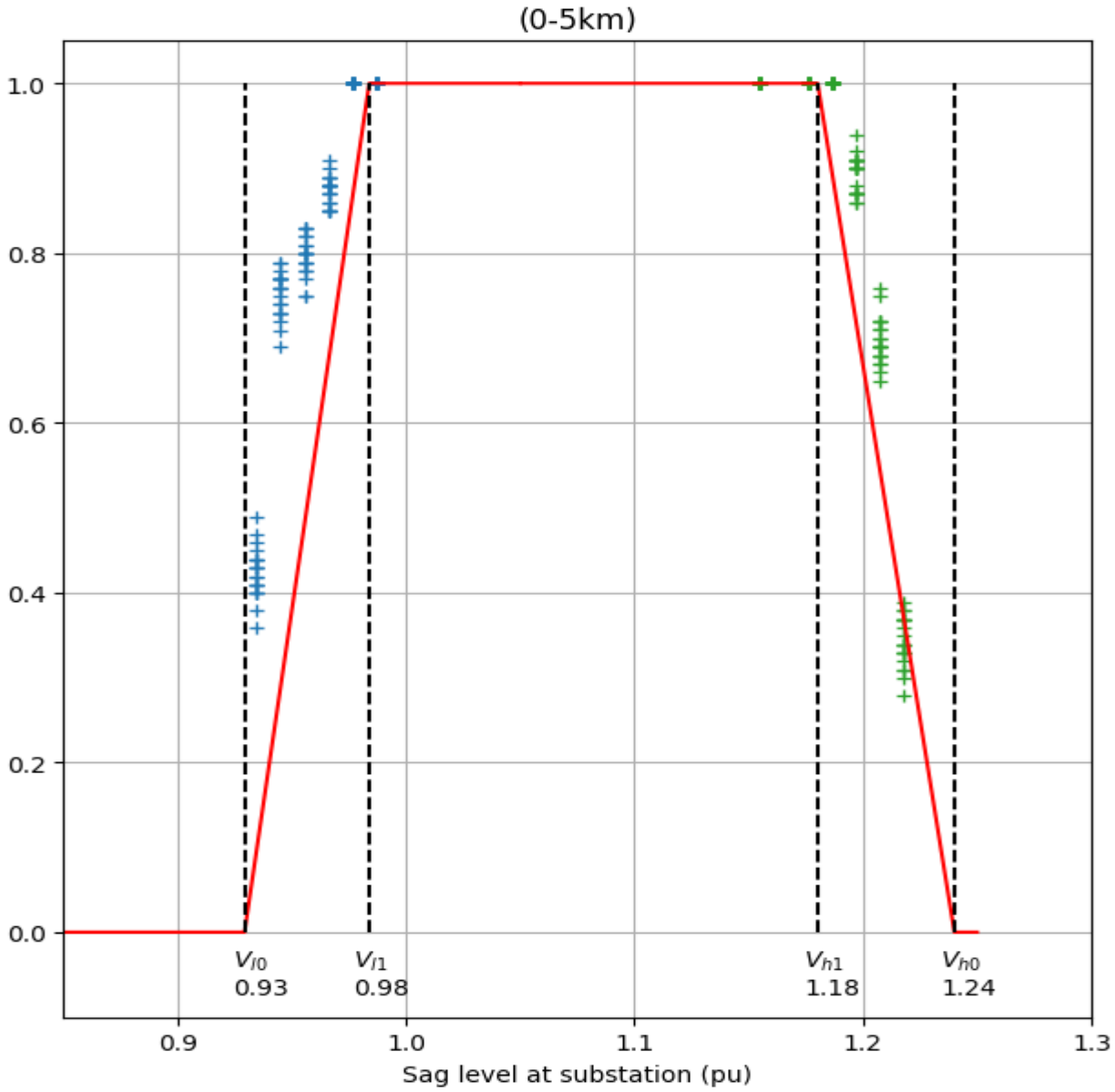


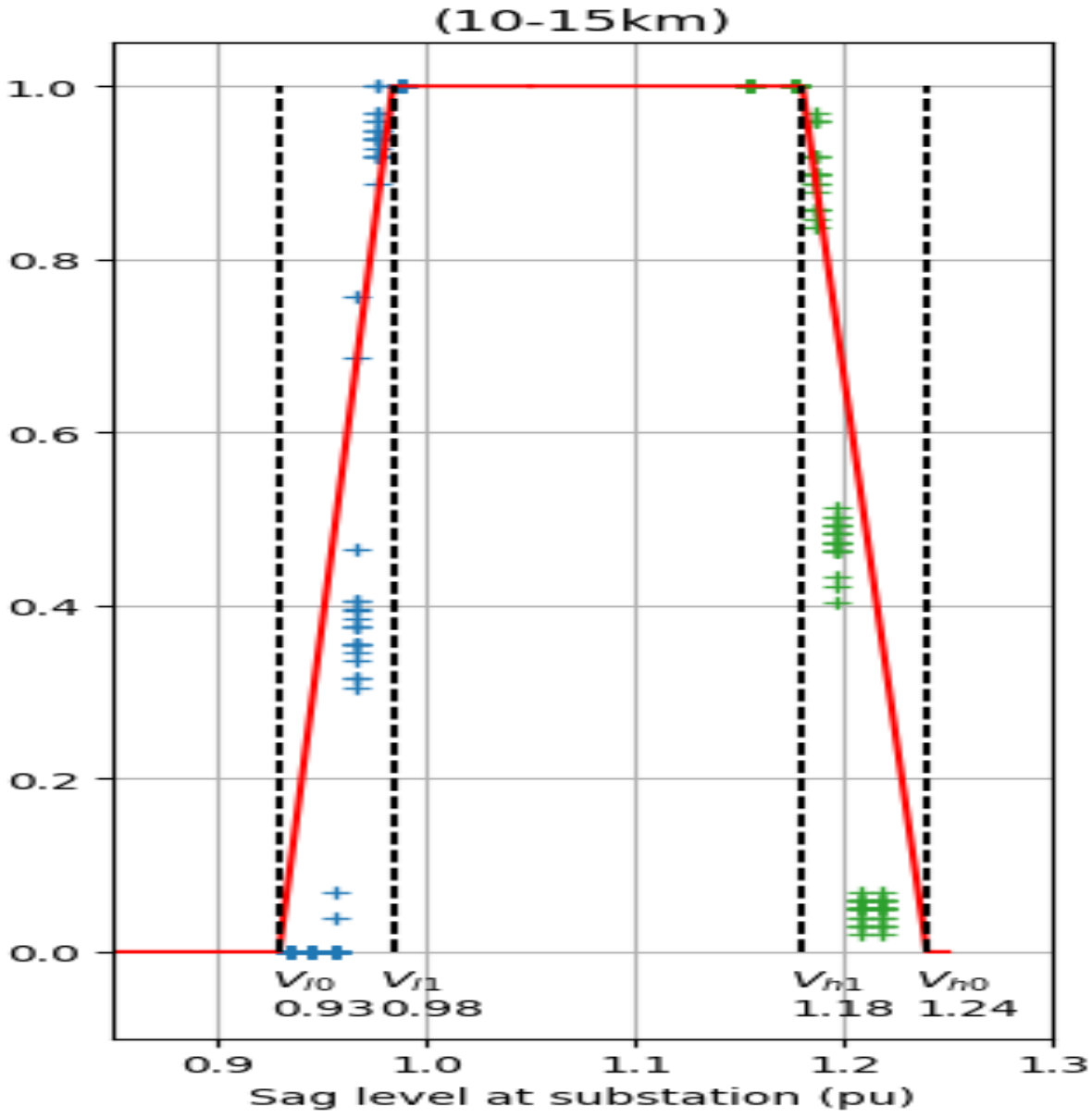


Preliminary values for DER_A trip characteristic

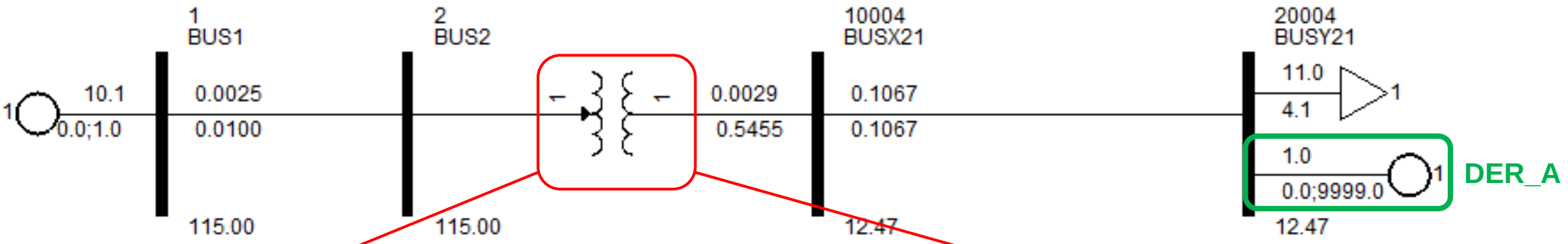


How does location of inverters on the feeder play a role?





Would a transmission planner see the same behavior from the aggregate model?



Substation

Substation step down transformer

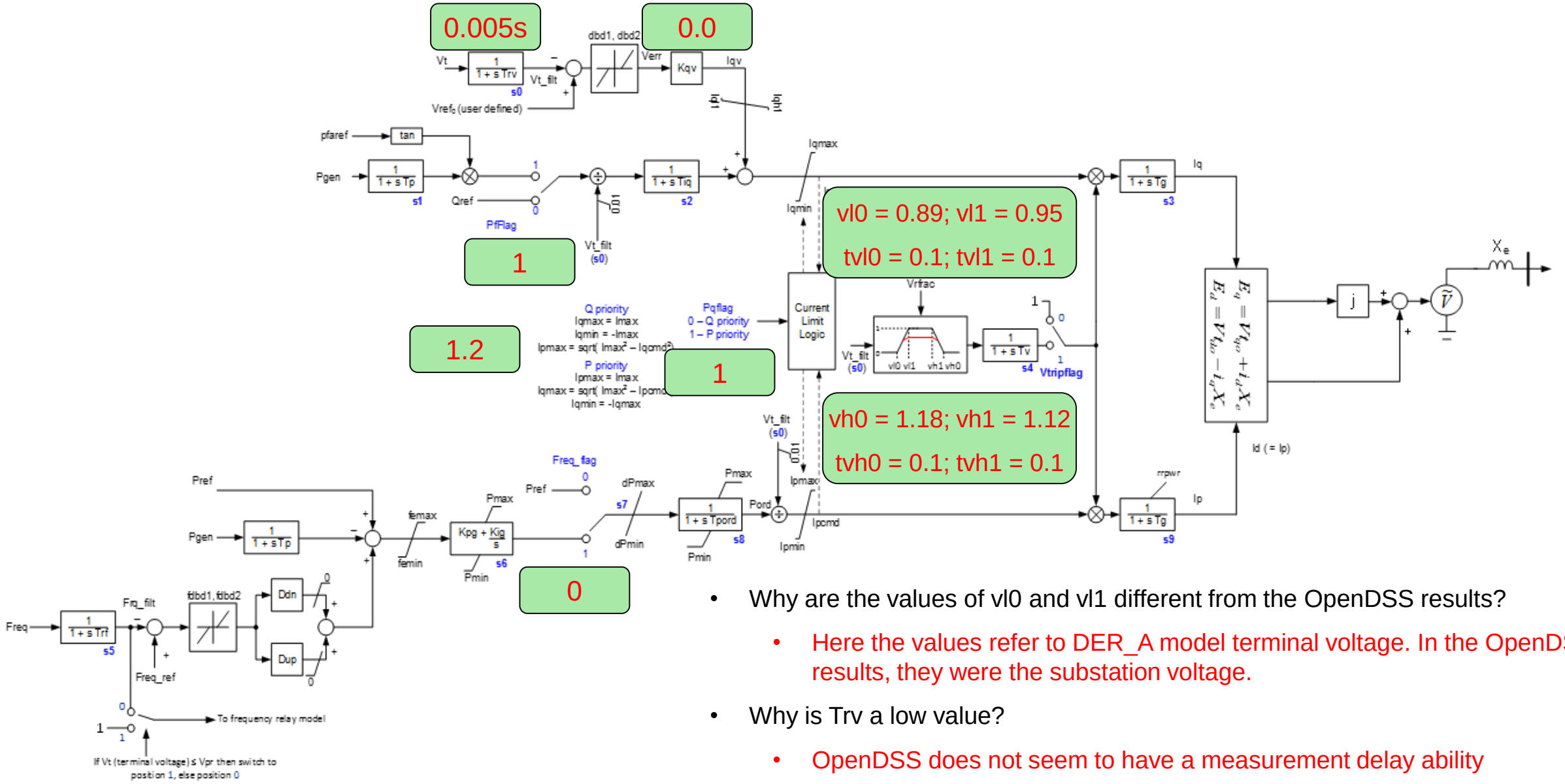
Equivalent feeder

Values of MVA, r, X & base kV from OpenDSS definition of the element

```
! HV/MV Substation connected Delta/grounded-wye
New Transformer.HVMV_Sub  phases=3  windings=2  buses=(HVMV_Sub_HSB, regxfmr_HVMV_Sub_LSB.1.2.3.0)
~ conns=(delta wye)
~ kvs=(115, 12.47)  kvas=(27500, 27500)
~ xhl=15.51  sub=y  subname=HVMV_Sub
~ wdg=1  %r=0.67202
~ wdg=2  %r=0.67202
```

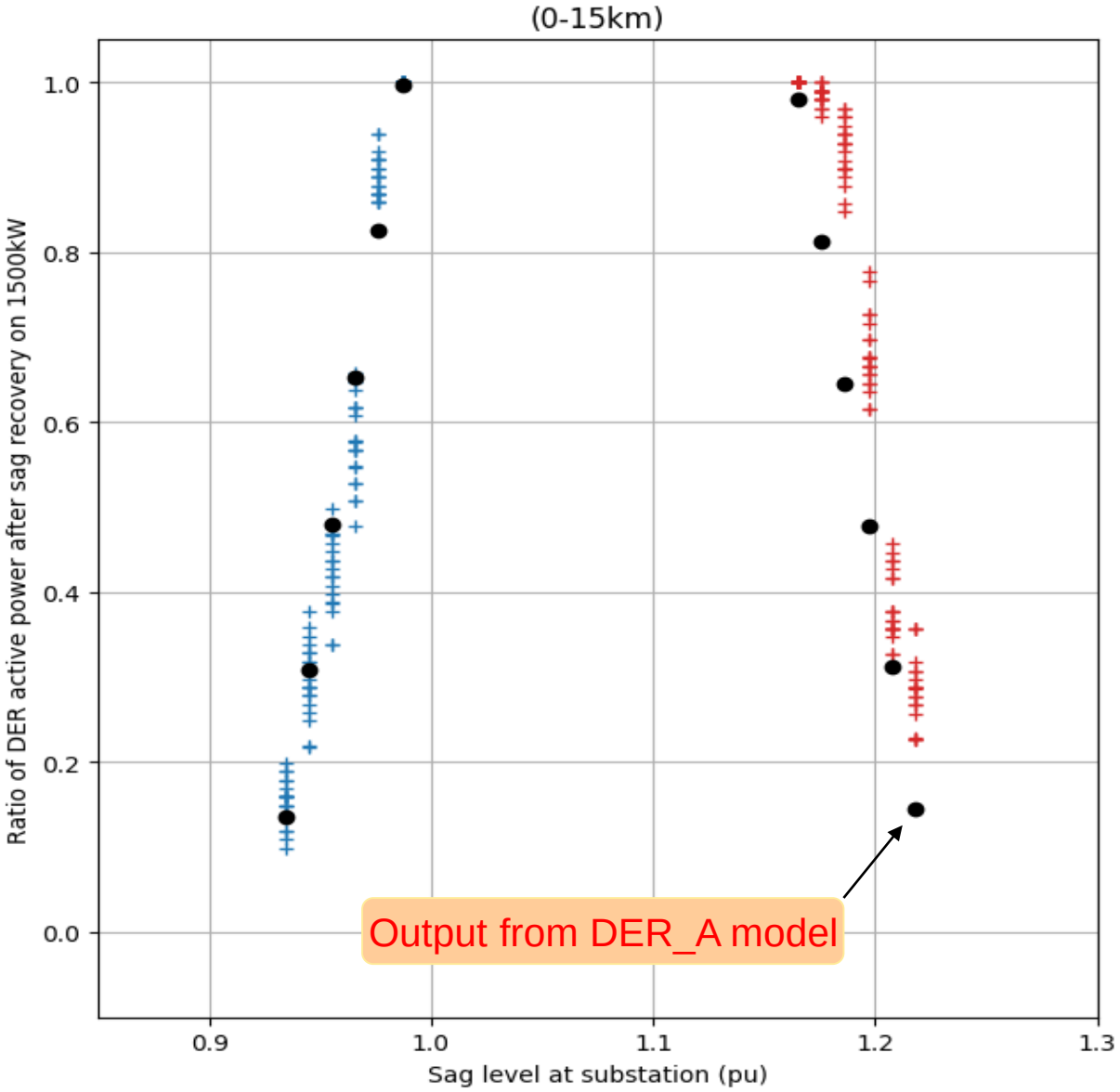
Values of r and X of the equivalent feeder have been assumed

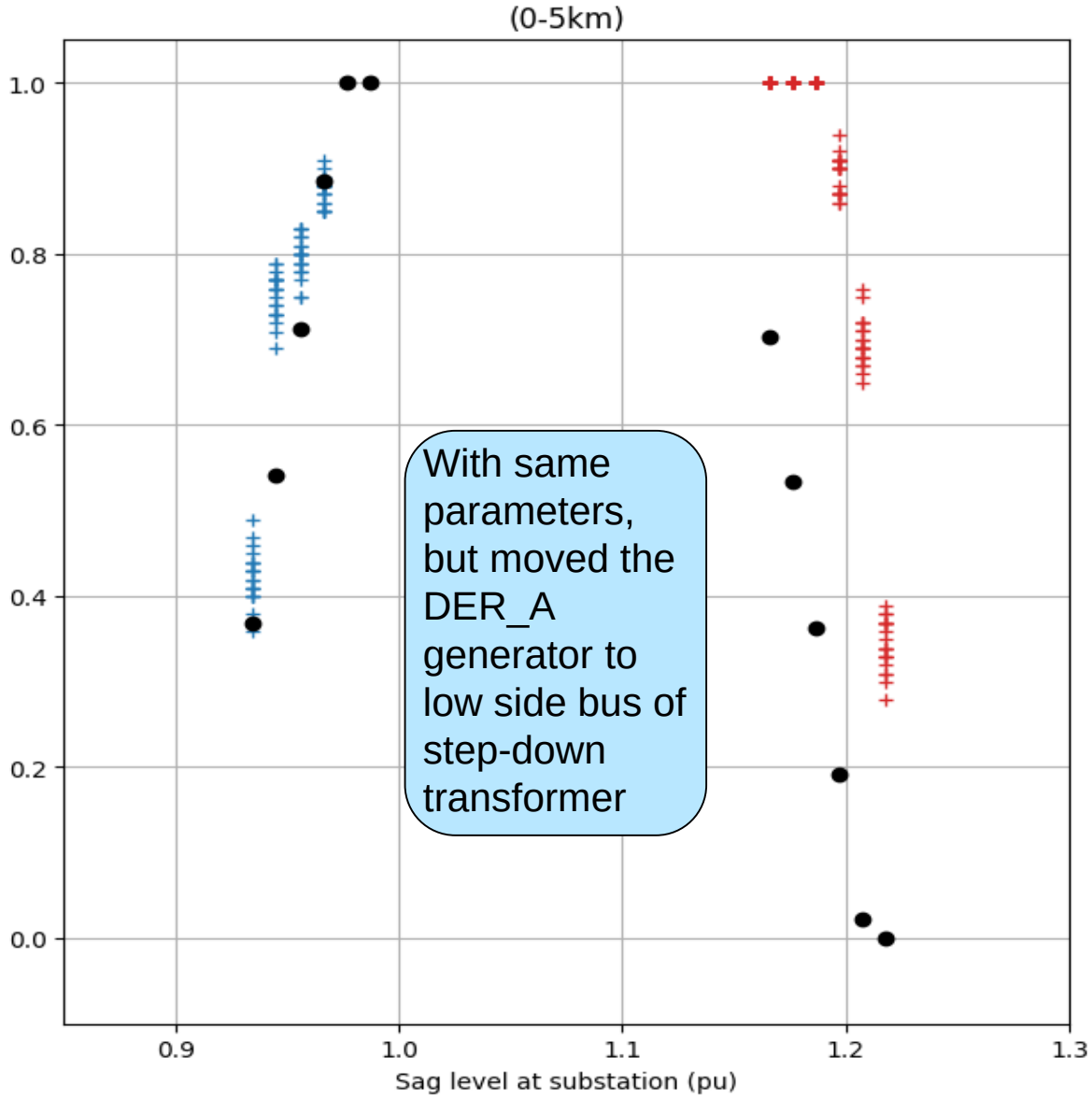
Parameterization of DER_A model assuming Group A



- Why are the values of vl0 and vl1 different from the OpenDSS results?
  - Here the values refer to DER_A model terminal voltage. In the OpenDSS results, they were the substation voltage.
- Why is Trv a low value?
  - OpenDSS does not seem to have a measurement delay ability

Comparison of results





Conclusions and open questions…

- It is possible to parameterize the aggregated model using detailed simulations
  - The response in positive sequence matches well
- How to generalize the DER_A trip parameters w.r.t.
  - Inverter location on feeder
- How does the parameterization expand to various different feeder configurations?
- Can we obtain equivalent feeder impedances?
- How to model advanced inverter functions?
- Impact of networked distribution grids?

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