Investigating Solutions to Voltage Increase on Distributed Generation Power Systems

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Client: Maquoketa Valley Rural Electric Cooperative (MVEC)

Maquoketa Valley Electric Cooperative

Background

As solar panels become cheaper and there is a larger push for green energy, more and more homeowners, farmers, and businesses are installing solar panels (Figure 1). Maquoketa Valley (MVEC) serves rural Iowa which has agricultural loads, residential, and some commercial loads spread across long, radial, single phase lines. With solar array installs currently reaching up to 110kW on some of MVEC's feeders, they are concerned that too much solar in places could result in an excess of power being put back onto the grid which in turn results in lines becoming overvoltaged which can lead to equipment damage. We were tasked with determining if changing the solar inverter power factor settings would be able to sufficiently reduce the voltage on distribution lines away from the overvoltage conditions.

Inverter Solution

In order to prevent the overvoltages on the system, we found that an inverter with power factor setting of 95% leading corrects the problem for the conditions we tested. Smart inverters as a rule have a capability of providing a power factor of up to 85% both leading and lagging. Smart inverters would be able to not only very quickly and autonomously respond to overvoltages when they happen but also provide support for future contingencies beyond the scope of what we tested.

Model Setup

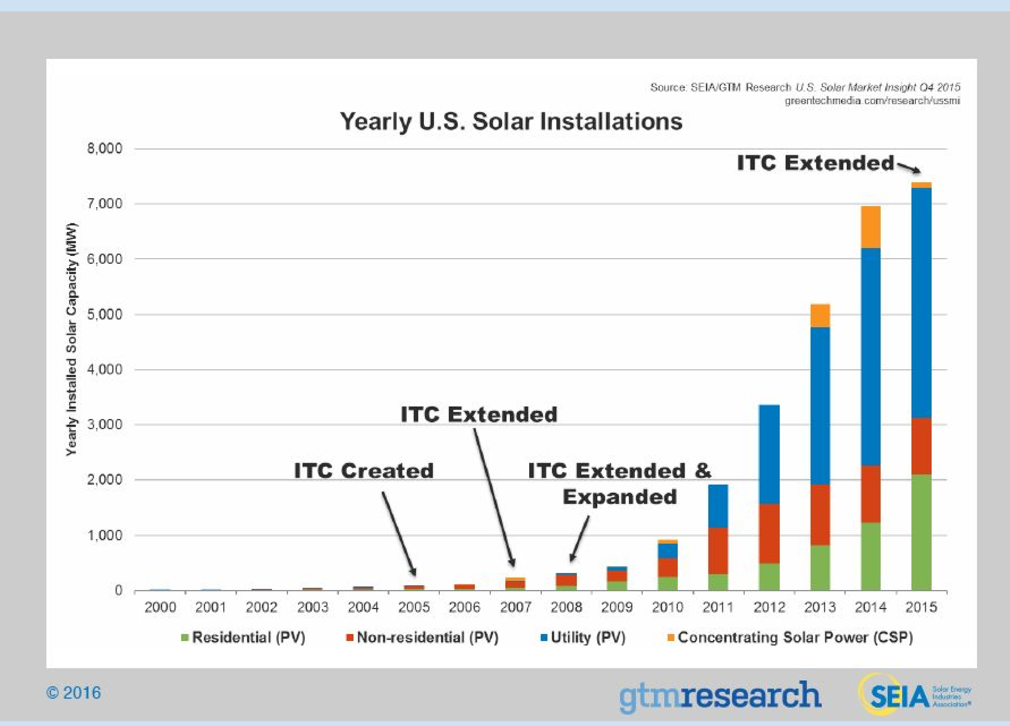


Figure 1: Yearly Solar Installations by sector also showing the creation and expansion of Investment Tax Credits (ITC) on solar Solar Energy Industries Association: www.seia.org/research-resources/solar-industry-data

Using MVEC's model and Windmil software we simulated high solar penetration for customers near the ends of the feeders. Distributed Generation (DG) nearer the ends of the feeders caused a higher line-voltage increase compared to DG nearer the substation. Using Advanced Metering Infrastructure (AMI) data for consumer daily loads, consumers were modeled as having a solar array sized to match their highest average daily load over 6 months.

Maximum solar irradiance in the Cedar Rapids area (source: NREL System Advisor Model, Figure 2), peaks in late April through early August. On May 4th, consumers tended to have low loads per the Supervisory Control And Data Acquisition (SCADA) data, and solar irradiance has reached its peak. Our model uses individual customers' load data for noon on May 4th, 2015. Residential loads tend to be at a daytime minimum at noon, while solar irradiance is maximized. Therefore, our model represents a worst case wherein voltage increases will be maximized due to high solar generation and low loads.

Solar panels are sized according to the average daily load of the consumer per the AMI data. The size of a solar panel corresponds to an average of 4.2 daily hours of sunlight, and a desired generation of 100% of consumer load. If this did not result in overvoltage then the DG sizes per branch were increased until branch overvoltage occurred.

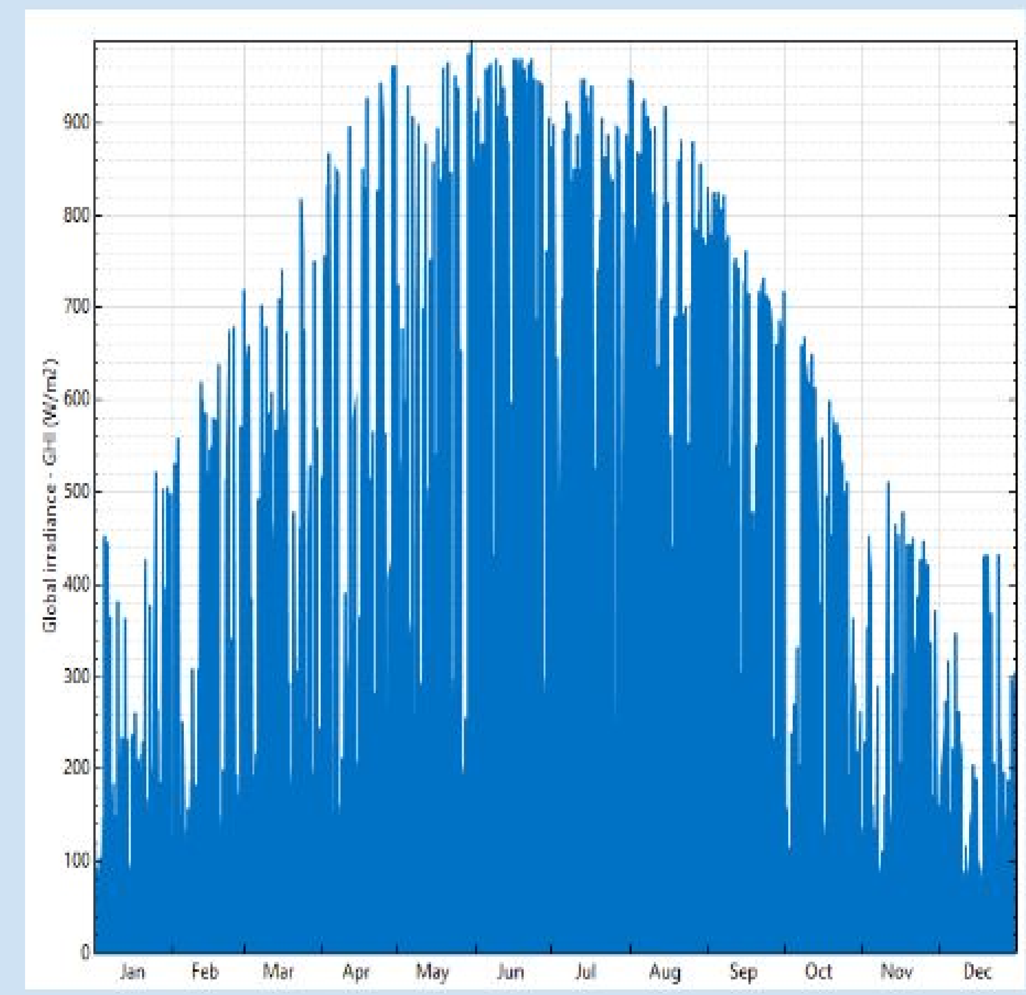


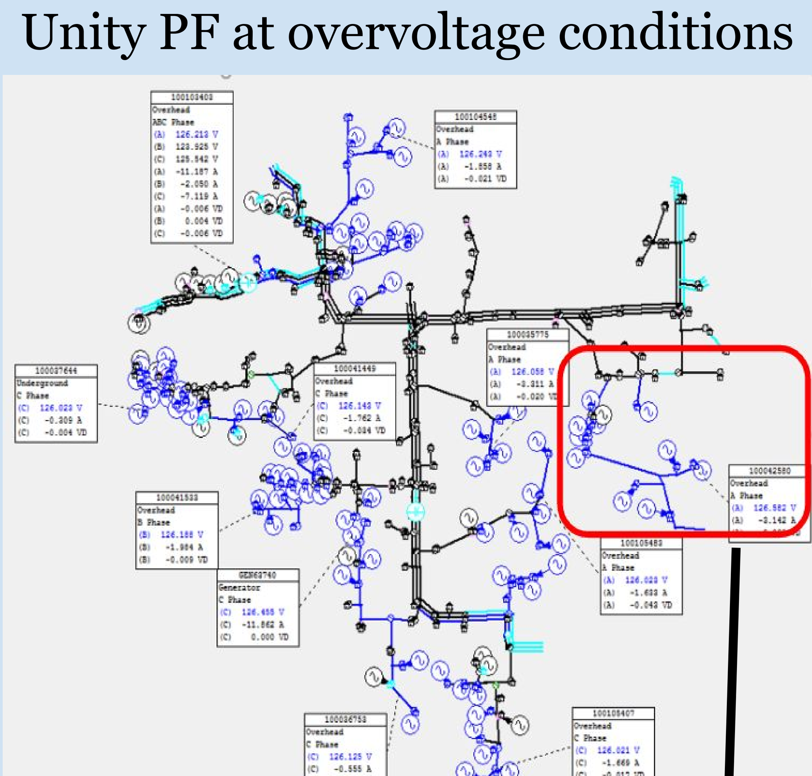
*Figure 2: Daily solar irradiance for the Cedar Rapids area for 2015.
Graph generated using National Renewable Energy Laboratory (NREL) System Advisor Model (SAM) software*

Color Scheme

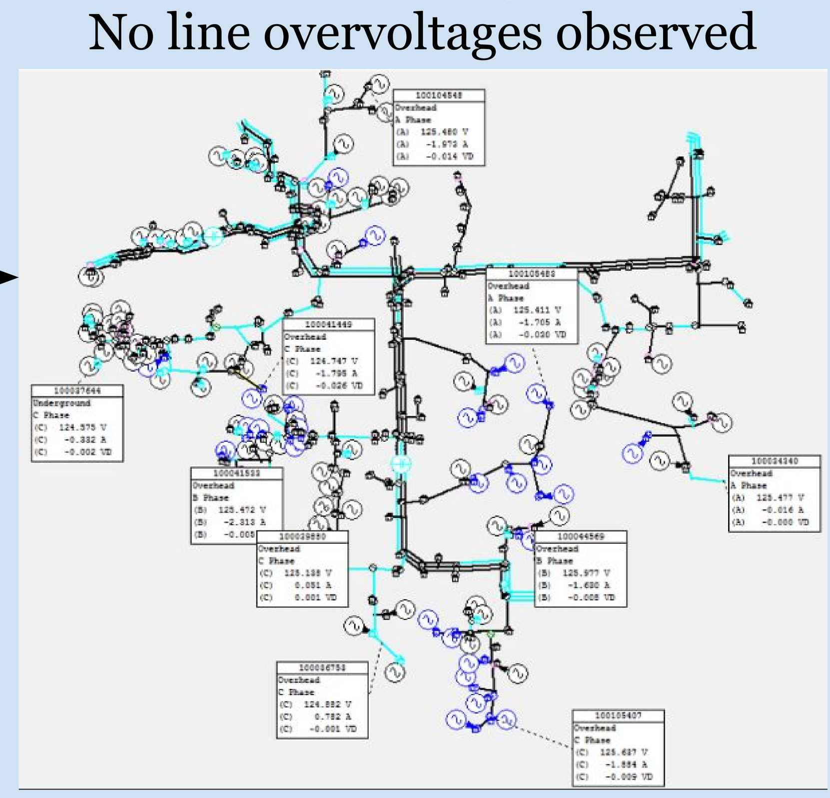
- Dark Blue is over voltage.
- Turquoise/Cyan is power factor below 80% leading or lagging.

Bernard Distribution Model:

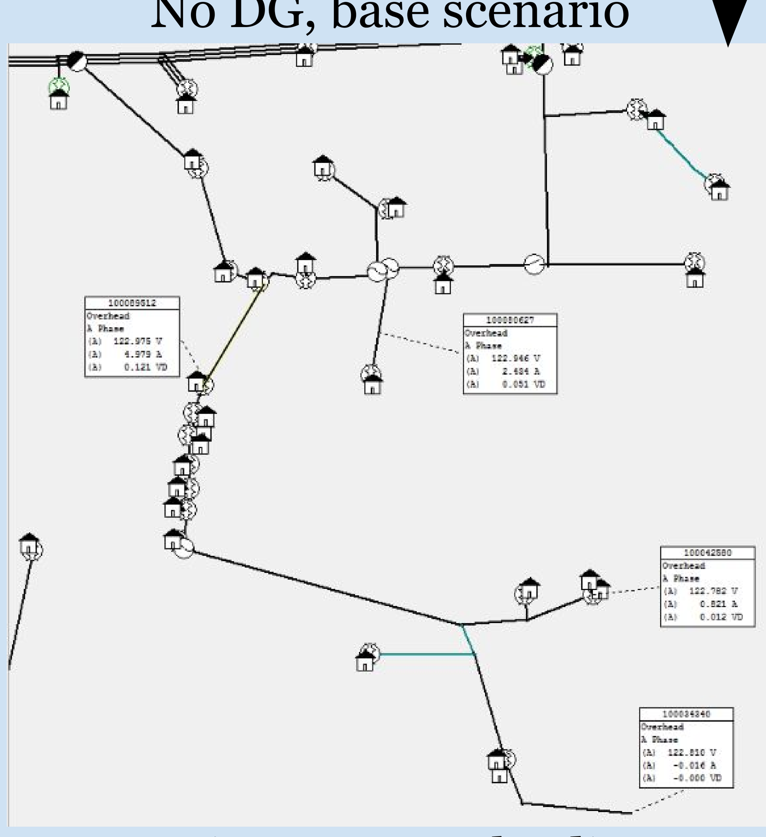
Generators near ends of lines
Unity PF at overvoltage conditions



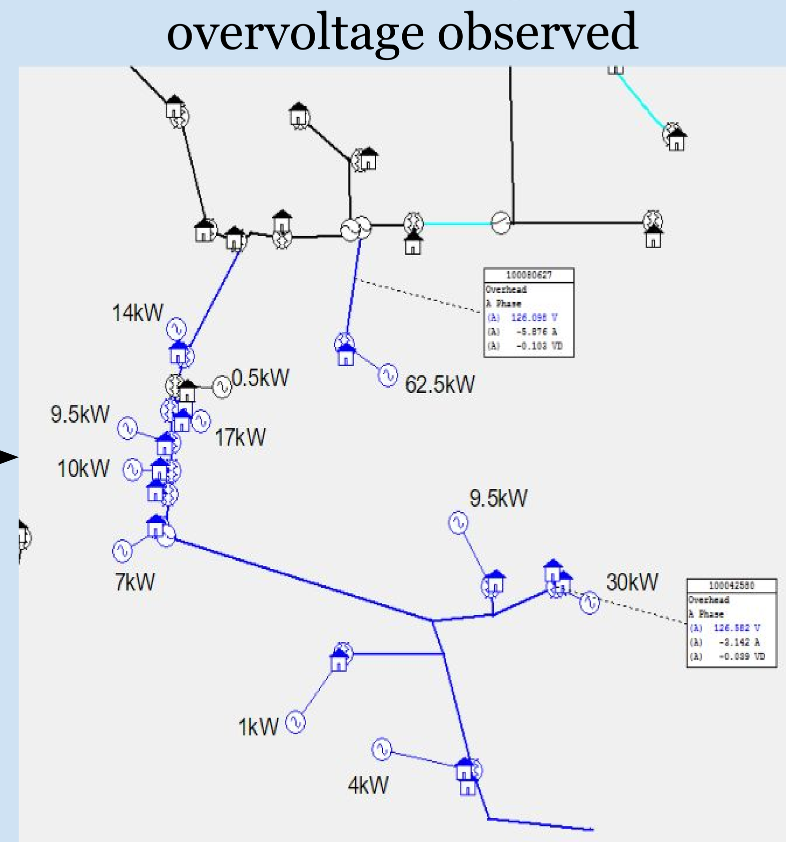
95% leading PF
No line overvoltages observed



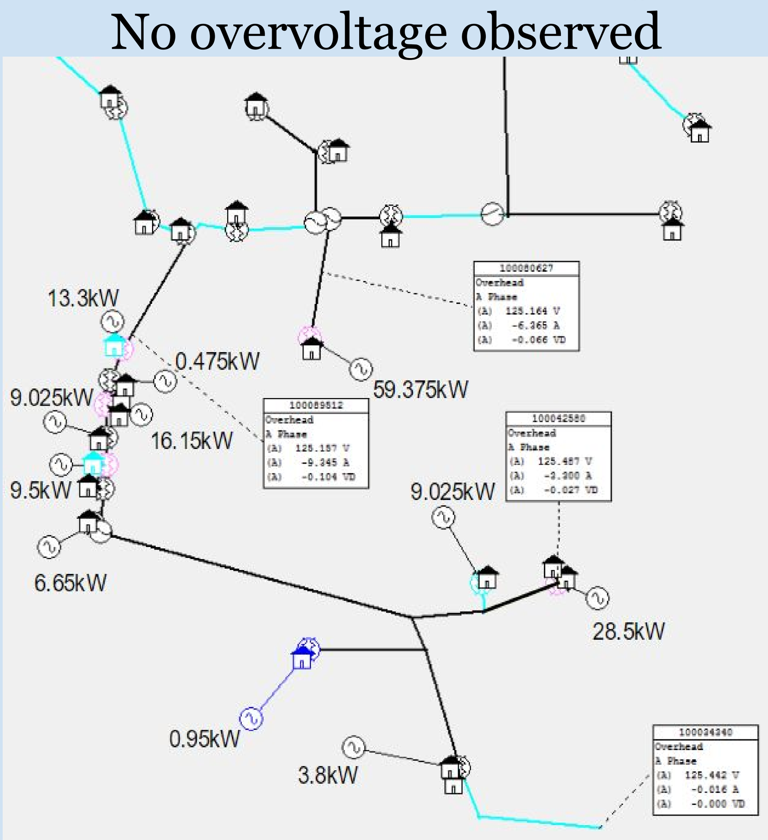
No DG, base scenario



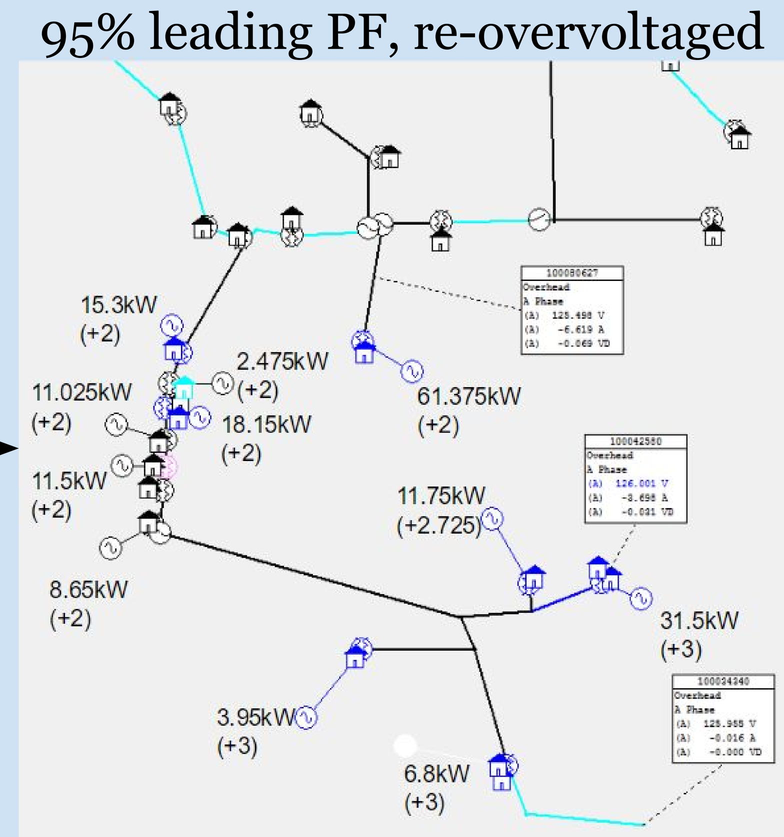
DG sized according to load, overvoltage observed



Same size DG, 95% leading PF
No overvoltage observed

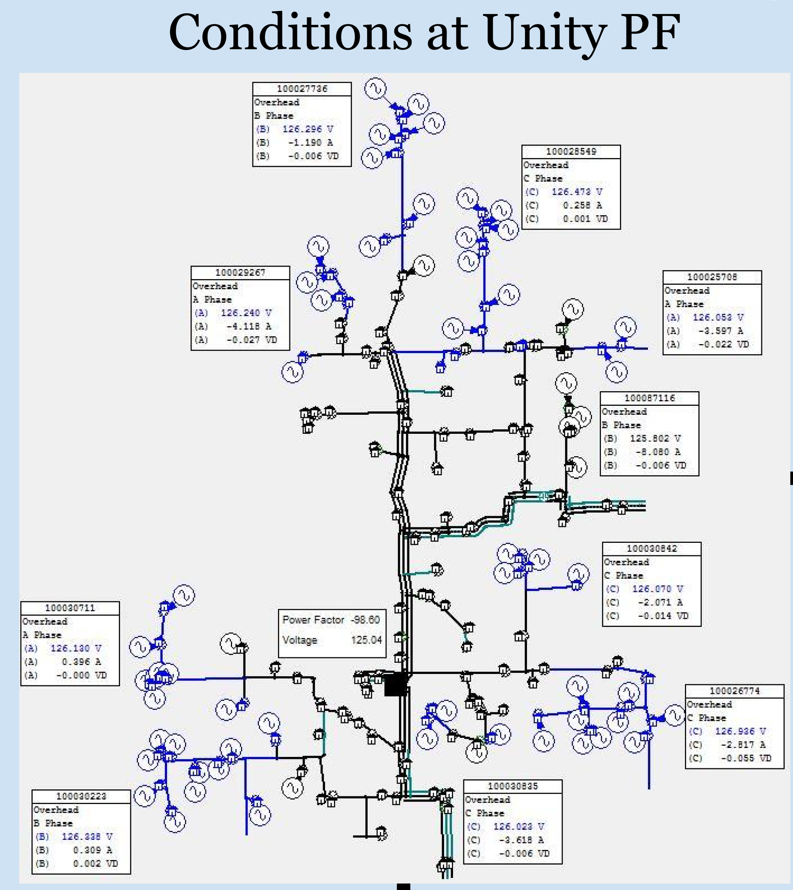


Each DG increased by 2-3kW at 95% leading PF, re-overvoltaged



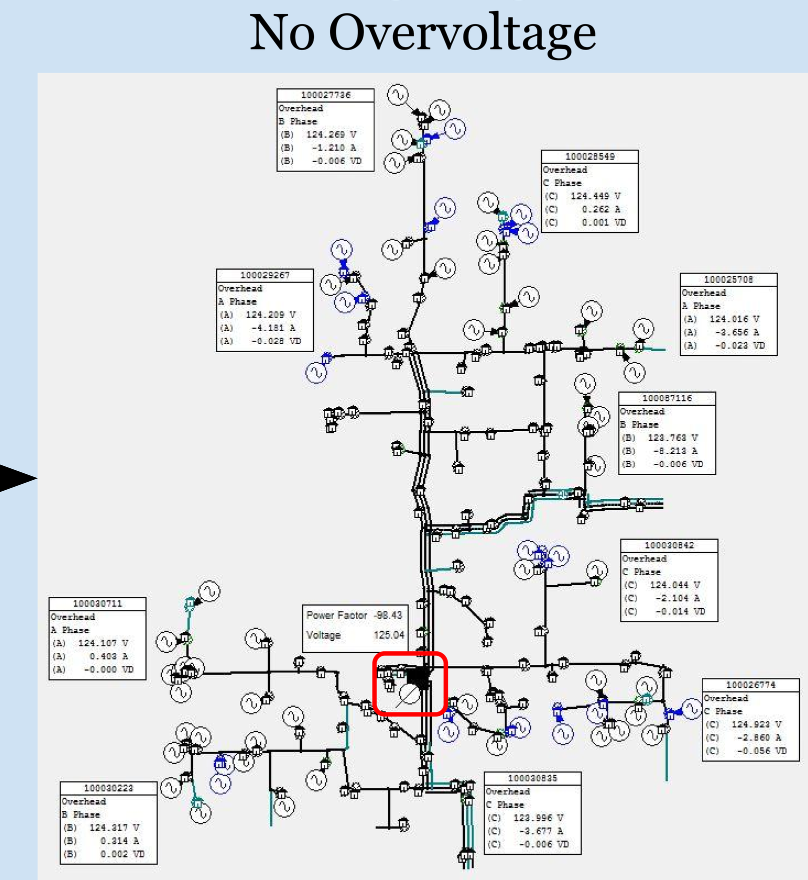
Backbone Distribution Model:

End of lines Case with Overvoltage Conditions at Unity PF

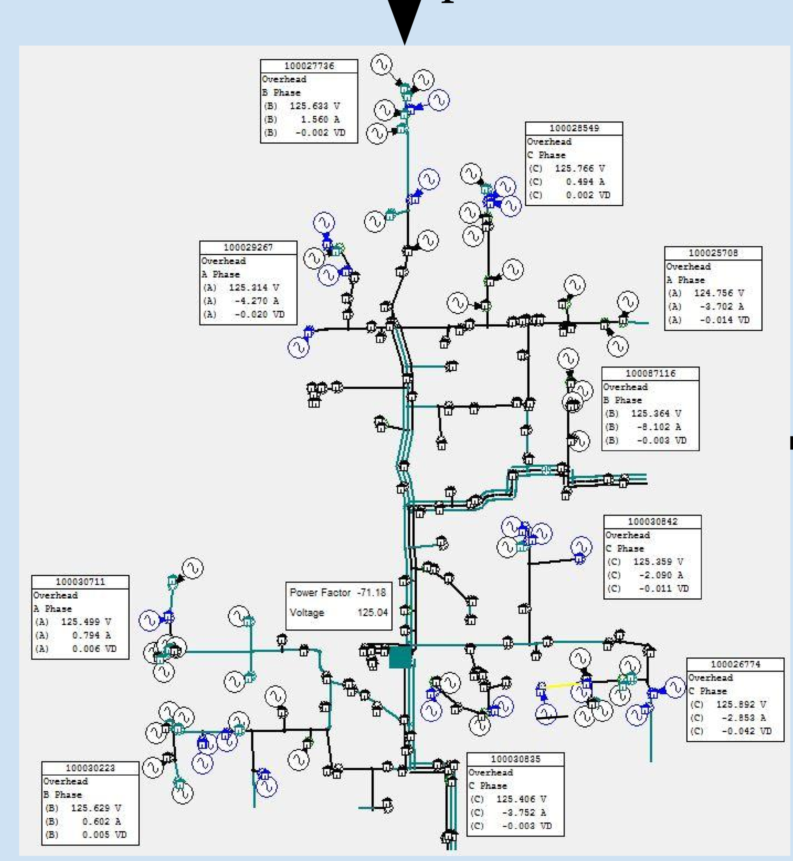


Adding Voltage Regulator Just Outside Substation.

123V Voltage Regulation.
No Overvoltage

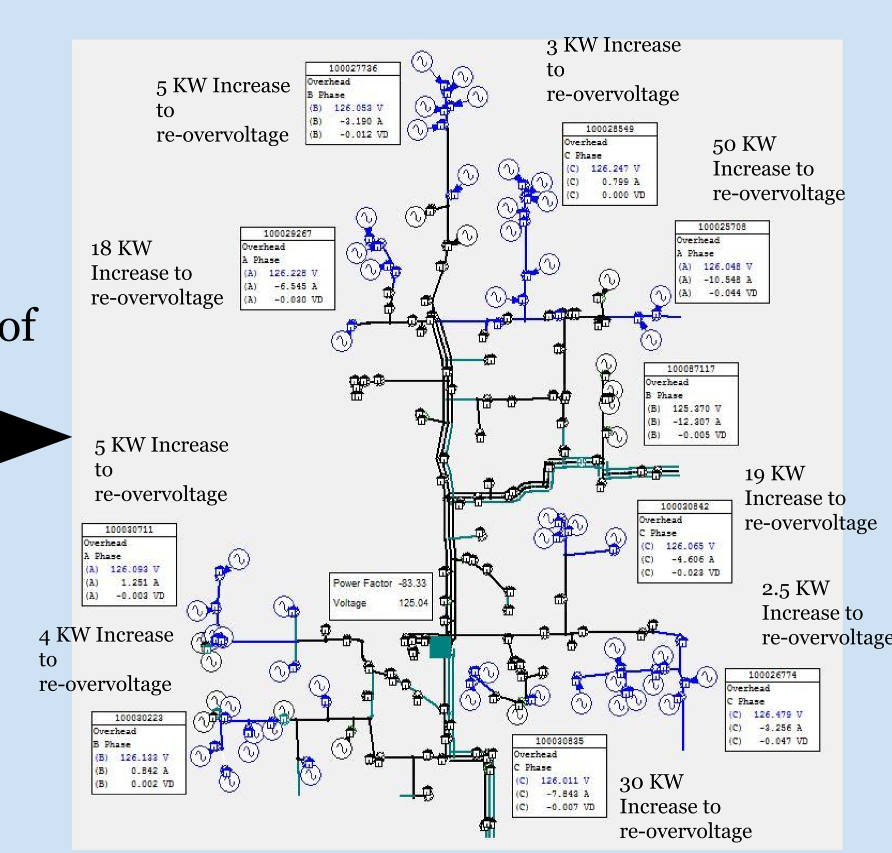


Changing every solar generator to 95% leading power factor.



95% Power Factor Leading
(No Overvoltage)

Adding kilowatts to each solar generator until overvoltage of the branch.



95% Power Factor Leading
(Re-overvoltage)

Possible Solutions

- Inverters set to a 95% Power Factor Leading.
- Load Tap Changing Transformers/ Voltage Regulation set to 123V. (Not a solution to all cases)
- Curtailment with Smart Inverters.
- Suggestion: Smart Inverter with grid-follow technology and autonomous Power Factor control.