An Investigation of the Impact of Photovoltaic Generation on a Utility Transmission System

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CONTENT

- Background
- Modeling assumptions
- Base case set-up and modeling the PV
- Study Results
- Conclusions

BACKGROUND

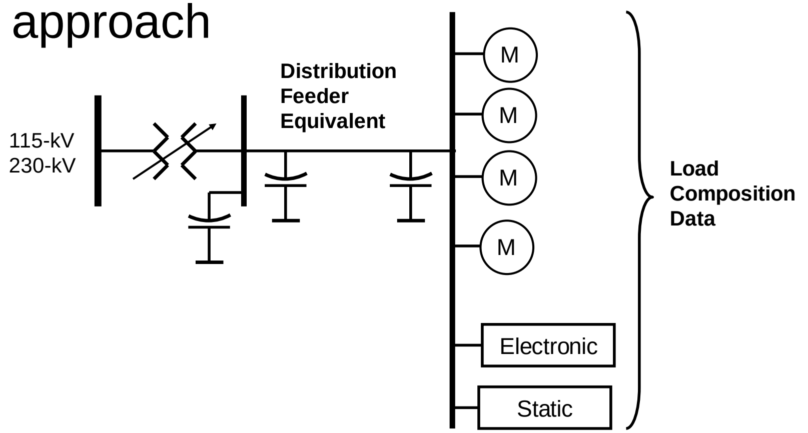
- Many North American regions expect that a significant amount of photovoltaic (PV) generation will materialize
- Tucson Electric Power Company (TEP) has recently seen significant interest in interconnection of PV generation
- PV generation is variable by nature – due to cloud formation and movement
- PV generation is connected by a power converter interface
- At the time of the study: total amount of PV proposed within the 5 year planning horizon was more than 150 MW, and by 2022 projected to reach 600 MW name plate capacity.
- The numbers above and the results discussed are based on information available in mid-2012, when this study work was done. These numbers are subject to change.

MODELING ASSUMPTIONS

- Load Modeling
- Modeling the PV generation

MODELING ASSUMPTIONS

- <u>Load Modeling</u>
  - The phase 1 new WECC composite load model was used
  - This model was applied to the entire WECC system, using the WECC load model data tool (LMDT)
  - In accordance with the current phase 1 release of the composite load model, we disabled stalling of the 1-phase air-conditioner motor load component
  - the tripping of any of the motor load components was disabled, since there was no specific data available for these setting for the large number of loads in the system; this is a pessimistic assumption, but for now seemed the more reasonable approach



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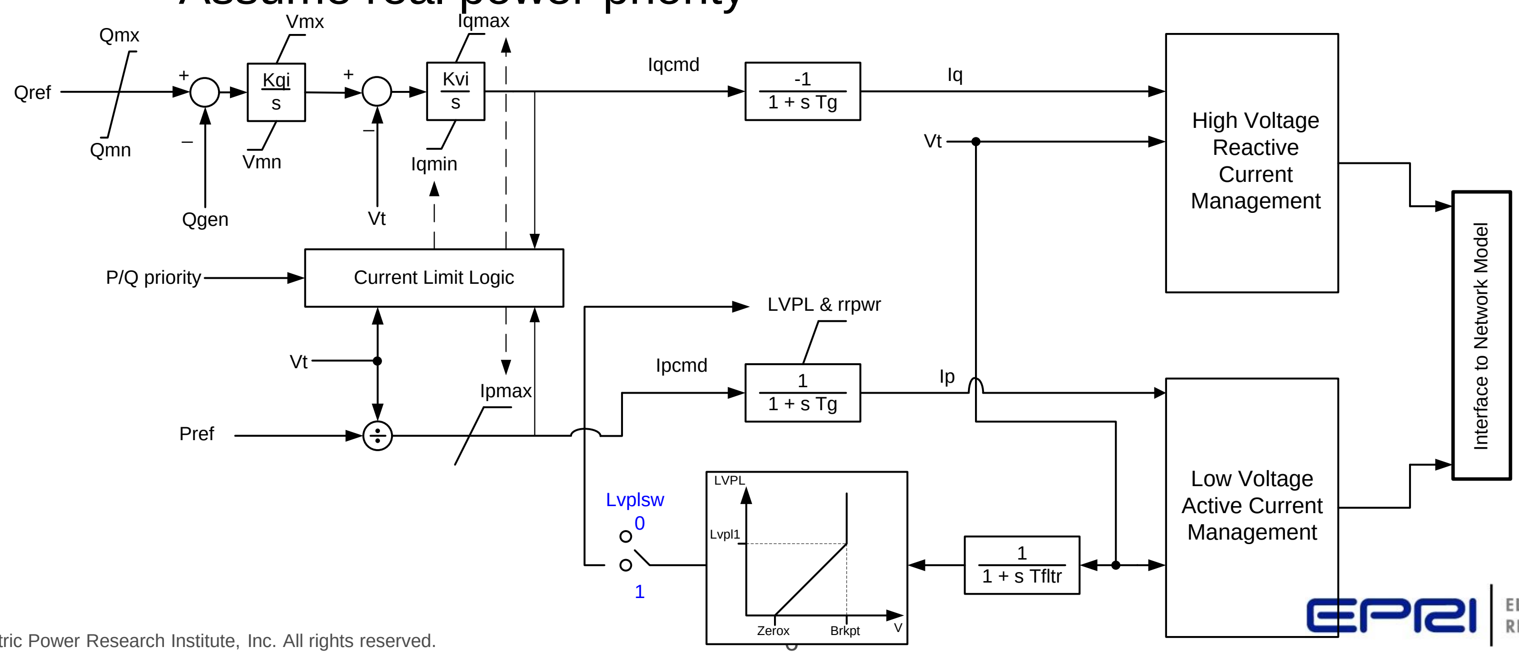
MODELING ASSUMPTIONS

- <u>PV Modeling</u>
  - In 2012, when the study was done, the distributed PV model currently being worked on by the WECC REMTF was not available
  - <u>Powerflow model:</u> modeled as constant P/Q and at unity power factor
  - <u>Dynamic model:</u> modeled using the PV1G and PV1E model in GE PSLF™
    - Assume unity pf and no voltage regulation
    - Assume real power priority

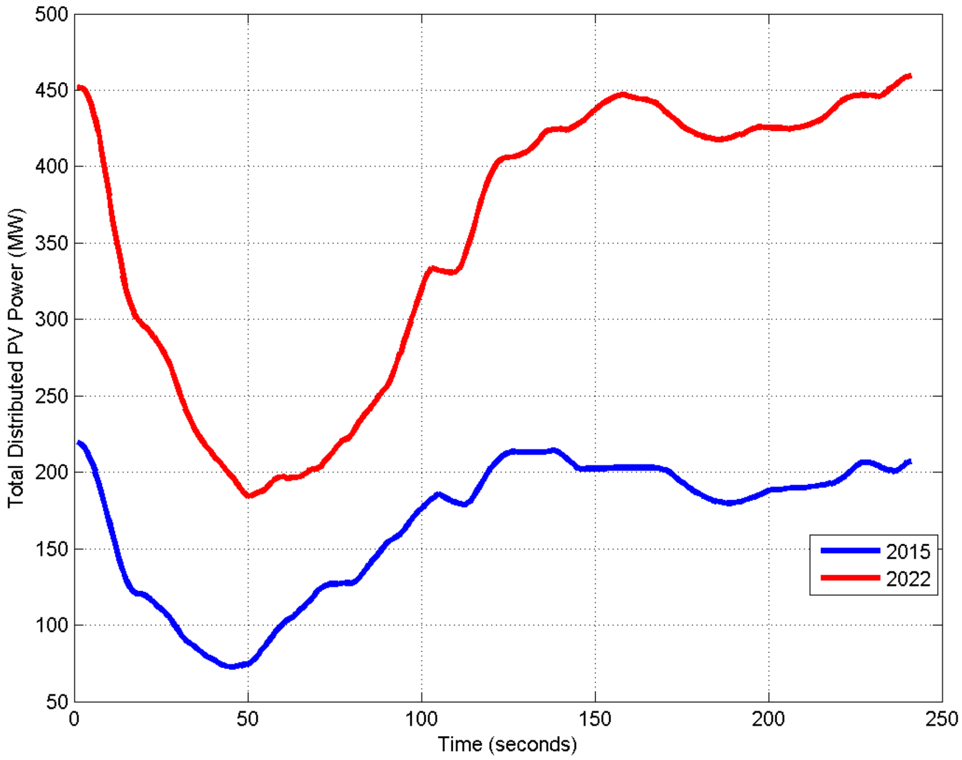


BASE CASE SET-UP AND MODELING THE PV

- A 2015 and 2022 case were established
- Based on a list of the projected amounts, and location, of both distribution and utility scale PV
- Used WECC case and consulted neighboring systems to try to get neighboring systems as close as possible to 2015 and 2022 scenarios – this is constantly changing
- The new PV generation was dispatched against other generators in Arizona, but outside of the TEP control area

BASE CASE SET-UP AND MODELING THE PV

- Plot of the largest swing in total installed PV generation on the TEP system, due to cloud movement– simulated day is June 21st. Source of the data is [1].



BASE CASE SET-UP AND MODELING THE PV

- In each case took the peak of the curve and appropriately scaled the PV generation in the case to reflect this amount
- This may not be exactly correct, since the day of this PV generation peak and peak-swing does not necessarily correspond exactly to the project peak-load day/hour
- Present planning criteria are based on deterministic rules thereby requiring looking at the coincidence of peak load and peak generation from the facilities(s) under study
- The approach here is a reasonable compromise, since the likelihood of all the PV generation being at peak name-plate capacity output at one time is quite low
- The values thus correspond to 70% and 74%, respectively, of name-plate installed capacity

STUDY RESULTS

- Ran extensive powerflow and QV runs
- Ran 69 time-domain simulations of various major EHV faults and tripping of transmission elements, with various sensitivity cases
- One major sensitivity was to:
  - Assume all distributed PV does not ride-through significant voltage dips (per IEEE Std. 1547™)
  - Assume all distributed PV does ride-through significant voltage dips
- Note by far the majority of the PV is distributed PV

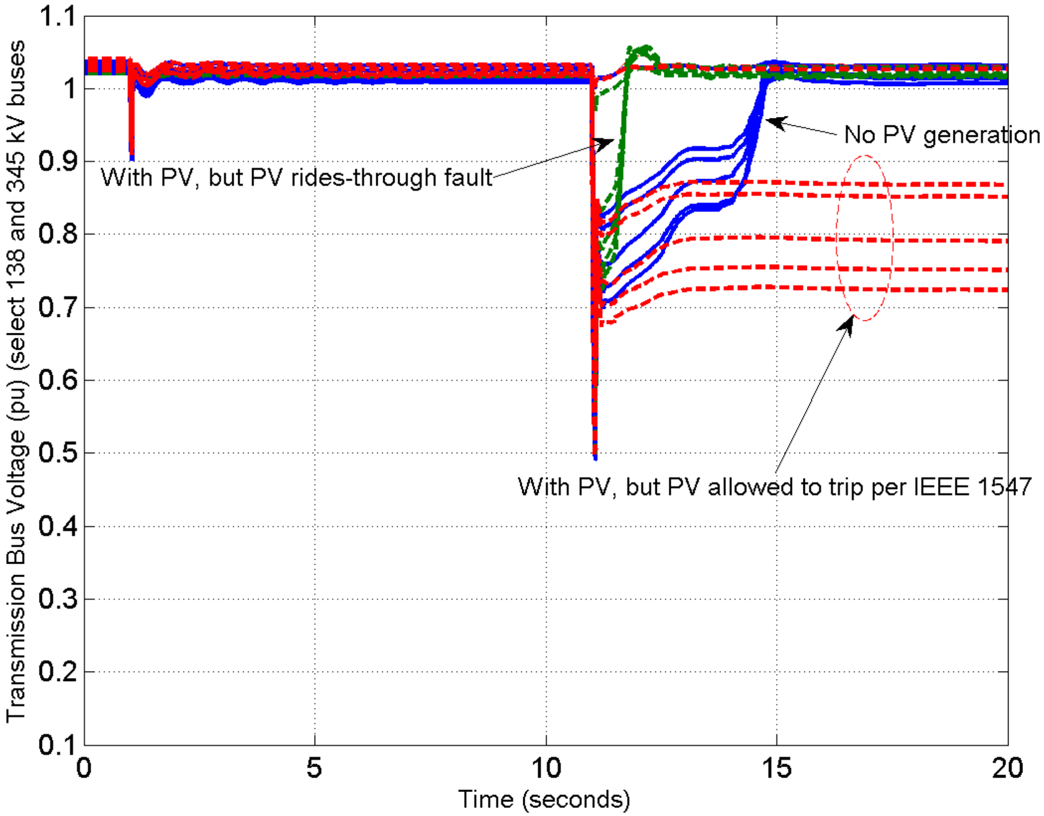
STUDY RESULTS

- Powerflow and QV Analysis:
  - No major new thermal violations due to PV
  - Local generation dispatch was not adjusted to allow the PV to displace local thermal generation. If local thermal generation was reduced, this would result in adverse system impacts due to reduced reactive resources
  - The voltage profile is slightly higher in the case with the PV generation. System voltages are generally higher both before and after most contingencies.
  - More detailed analysis will be needed for lighter-load conditions (i.e. non-peak conditions), as under these conditions the additional generation from PV may potentially give rise to over-voltage conditions.

STUDY RESULTS

- Allowing distributed PV to trip during faults, is not a good thing

Example N-1-1 condition



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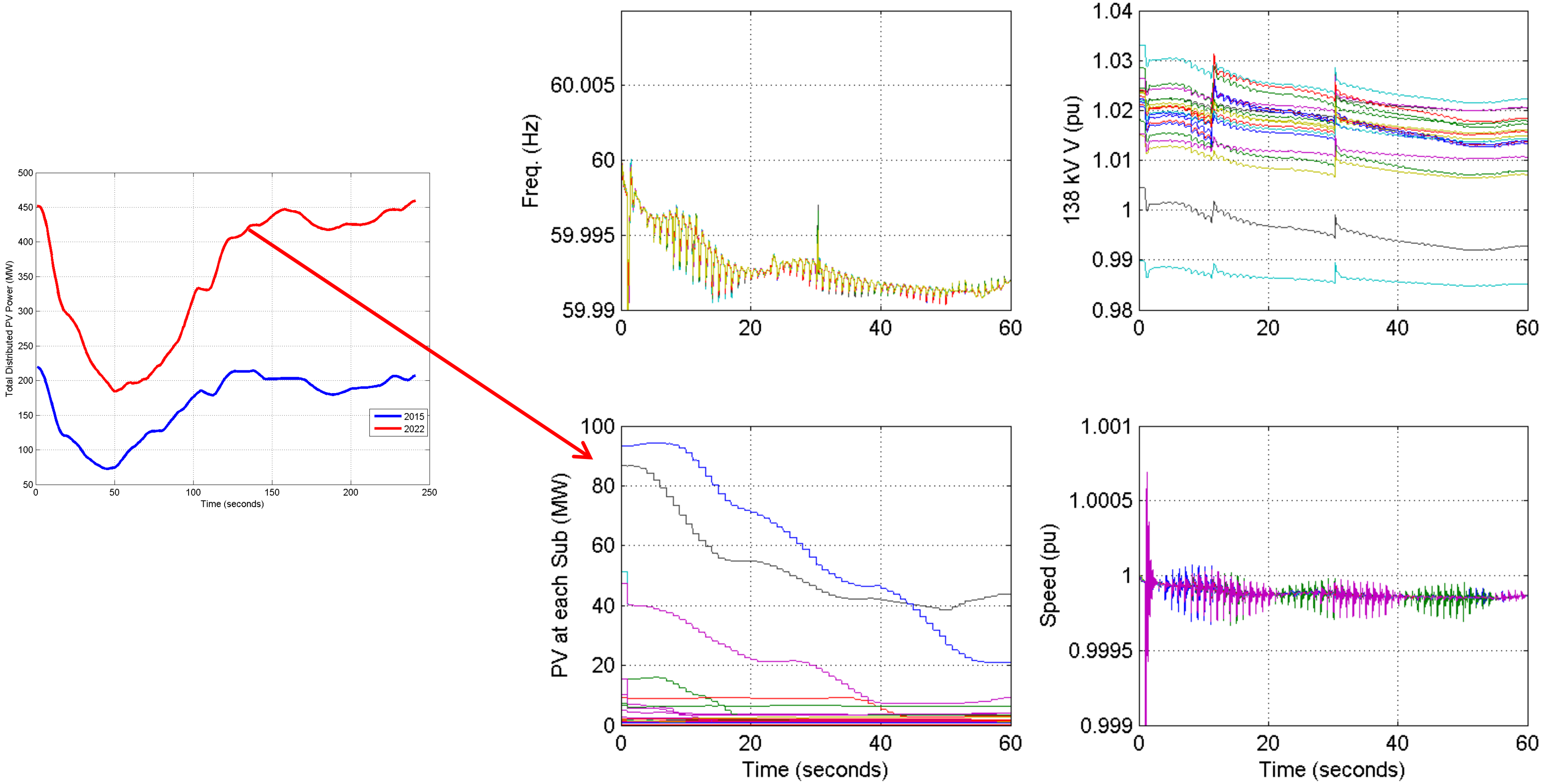
STUDY RESULTS



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CONCLUSIONS

- The addition of the PV generation does not appear to have an adverse effect on system steady-state conditions. (Caveat: need to study light load conditions and different local generation dispatch scenarios)
- For the dynamic simulations we see that the system voltages, in general, recover faster and settle higher with the PV generation in the system**, if we assume that all of the PV generation is able to ride-thorough transmission faults**.
- The most challenging aspect of the performance of PV will be operational, namely load/generation balance, frequency control, and voltage regulation. These are manageable issues, but as indicated in the literature, they may start to present a challenge as the percentage of penetration goes beyond 20% [2].

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References

[1] T. N. Hansen, “Grid Stability Analysis Project: Report of the Solar Generation Modeling Phase to Quantify the Impacts of Cloud Passing Created Solar Generation Variability on the Electrical Grid”, reported issued April 24, 2012 to TEP; Utility Solar Engineering, LLC

[2] US Department of Energy, “20% Wind Energy by 2030: Increasing Wind Energy’s Contribution to US Electricity Supply”, July 2008 (http://www.nrel.gov/docs/fy08osti/41869.pdf)