Validation of Grid Integrated PV and Storage Control Methods

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INTRODUCTION

- Validate results from a database-based simulation of Photo-Voltaic(PV)+Storage+Control+Grid(PSCG)
- Simulation examines various control methods on a real Wisconsin grid using a commercial modeling tool, Synergi[1]
- Simulation monitors kW Into Grid, kVAR Into Grid, Losses, State of Charge(SoC),Load-Tap Changer(LTC) Position, and a total of over 30 variables related to the simulation[2]
- Uses robust statistics to up-sample changing solar irradiance and loads data local to test feeder

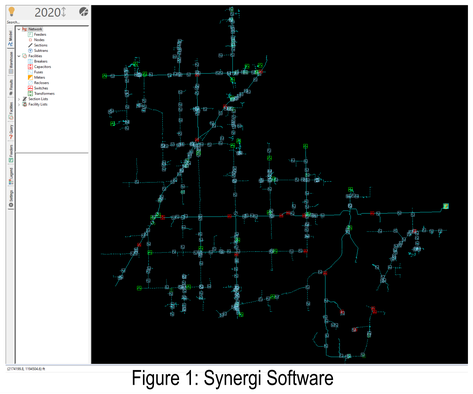

Figure 1: Synergi Software

METHOD

- Validation takes results from the PSCG simulation, builds the input file for the Synergi commercial modeling tool, runs a simulation pass in the modeling tool, then applies statistics to compare simulation data vs model data
- Validation provides metric for accuracy of PSCG simulation run using a tool(Synergi) which itself is validated through decades of use.

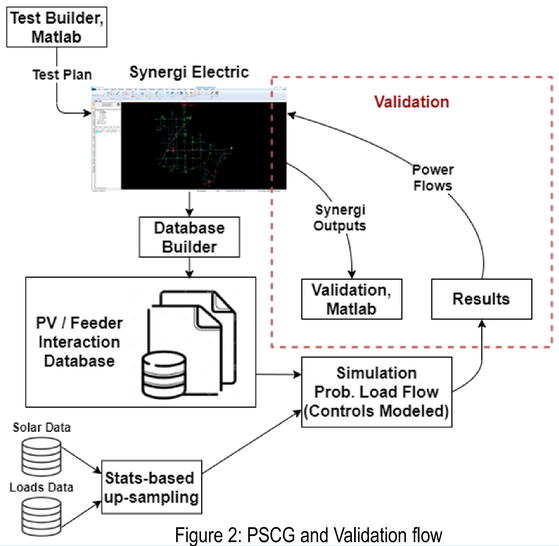

Figure 2: PSCG and Validation flow

RESULTS

- Challenge is to confirm accuracy of PSCG simulation against results provided from Synergi
- First pass of validation showed RMS error of simulation vs model at .767 Volts shown by an offset between PSCG Simulation Volts(PSCG Volt) and Synergi Model Volts(Synergi Volt)

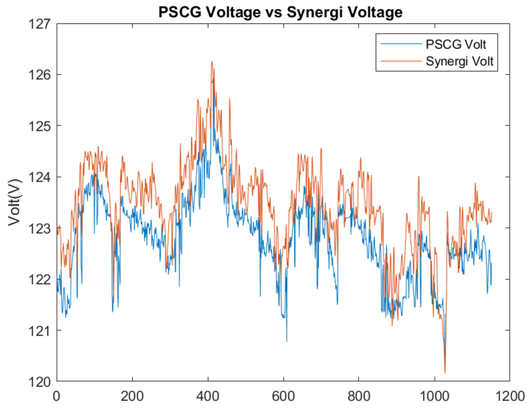

Figure 3: PSCG vs Synergi Voltage, Pass 1

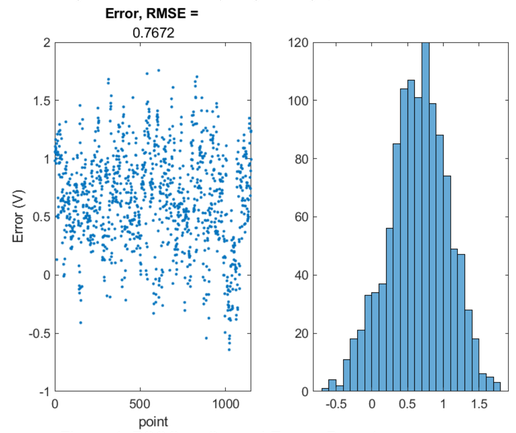

Figure 4: PSCG vs Synergi Errors, Pass 1

- Collective errors show a wide range of +1.8 Volts to -.7 Volts.
- It was found that Load Tap Changer(LTC) position was the root of the problem.
- LTC presence in distributed generation(DG) systems often cause difficulties in voltage regulation due to their nonlinear characteristics in that they are typically uncontrollable.[2]

RESULTS

- LTC position modeled using a quadratic fit of $S = \phi\Theta = a_1 Load \cdot a_2 PV_{kW} \cdot a_3 PV_{kVAR} \cdot a_4 Direction$
- Obtained rms error of 0.2759 of LTC position
- Added high-resolution database and removed data outside operating range of real grid
- Resulting simulation with control adjustments yielded a 7x improvement in RMSE

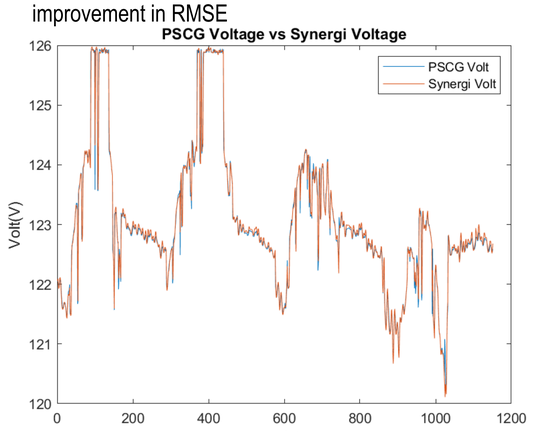

Figure 5: PSCG vs Synergi Voltage, Pass 2

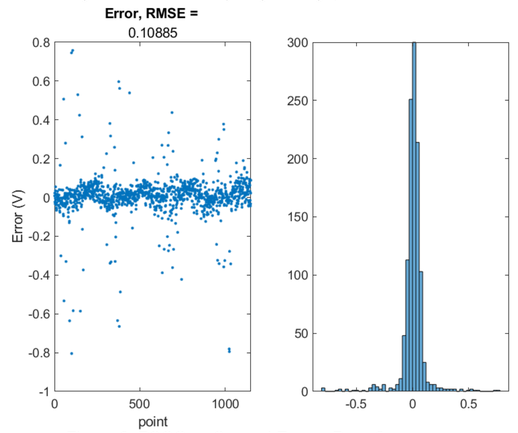

Figure 6: PSCG vs Synergi Errors, Pass 2

- Errors show clustering about 0 with very few outliers which tend to occur specifically at points where there is a previous extreme rate-of-change.

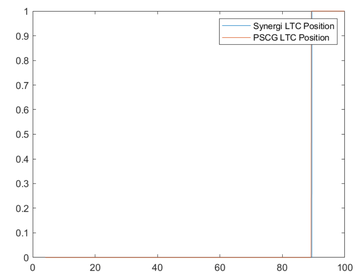

Figure 7: Correctly modeled LTC position after first validation failed

CONCLUSION

- The validation tool was utilized to prove a simulation using a system comprised of a PV array with battery storage integrated into a distributed grid.
- The validation tool succeeded in identifying a flaw in the original simulation and specifically what was causing the flaw.
- By correctly modeling the LTC, the RMS error is significantly reduced in the output voltage of the simulation.
- The control structure for the simulation is modular. Therefore the validation routine works for any set of outputs given from the simulation.

FUTURE WORK

- This is a relatively small step in a large project partnering with WE Energies and DNVGL.
- The total scope of the project is to develop a simulation with various controllers that will accurately model many parameters of the PSCG system.
- These parameters could then be used to investors and builders to determine the affect of X amount MV PV array with X amount MWh battery to see curtailment time, affect on the feeders, voltage stability, even opportunity for contracted capacity, frequency support and voltage support.

CITATIONS

[1] "Power distribution system and electrical simulation software – synergi electric," https://www.dnvgl.com/services/power-distribution-systemand-electrical-simulation-software-synergi-electric-5005, accessed: 04/18/2021

[2] B. Armstrong, A Nasiri, "Energy Storage for Increasing Solar PV Capacity and Improving Voltage Dynamics in Distribution Systems," NSF Center for GRid-connected Advanced Power Electronic Systems (GRAPES) Webinar, August 25, 2020.

[3] C. Gao and M. A. Redfern, "A review of voltage control techniques of networks with distributed generations using On-Load Tap Changer transformers," 45th International Universities Power Engineering Conference UPEC2010, Cardiff, UK, 2010, pp. 1-6.

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FOR FURTHER INFORMATION

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