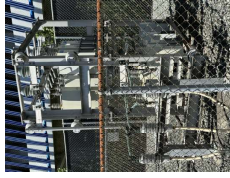


Sizing Substation Capacitor Banks



PSE seeks analysis and recommendations to resize their capacitor banks for better voltage control to address:

- Increased load on the grid from sources such as electric vehicles and data centers,
- Customers and electronics sensitivity to voltage fluctuations due to switching of oversized substation capacitor banks
- Maintaining nominal voltage and improving efficiency of power delivery

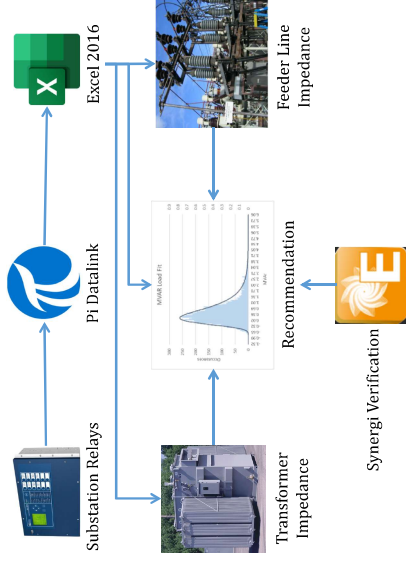
Substation Capacitor Bank Sizing Tool

Design a tool that output recommendations regarding the ideal substation capacitor bank size using selected year data input. This tool needs to be capable of the following tasks given from Puget Sound Energy :

- Capable to work with Pi Datalink to retrieve substation data
- Analysis and calculations of Reactive Power (MVAr), Complex Power (MVA), Capacitor bank switch adjusted MVAr: from data
- Give a result of load profile throughout the day (By 1 hour interval)
- Graph MVAr Load Fit as a result in a histogram to check if it fit our function

From the result the tool will give user the suggestion for the maximum stages of switched (staged) capacitor bank

Tool Design and Implementation



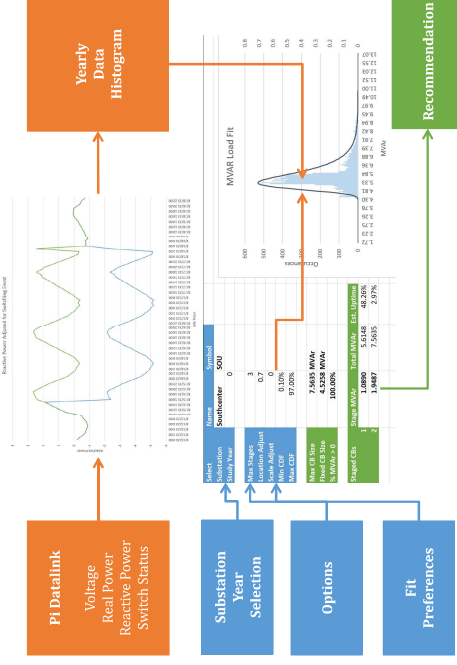
Synergi Verification

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UNIVERSITY of WASHINGTON

ADVISERS: JACLYN ERIKSSON, ROY CHAN, COLIN O'BRIEN

SPONSOR: PUGET SOUND ENERGY

Microsoft Excel Tool



Synergi Testing/Verification

Before Tool Implementation:

Sub	Sales Transformer Factor	Demand	NPS	Amps	Circuit Breaker	Safety Summary
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After Tool Implementation:

[illegible]

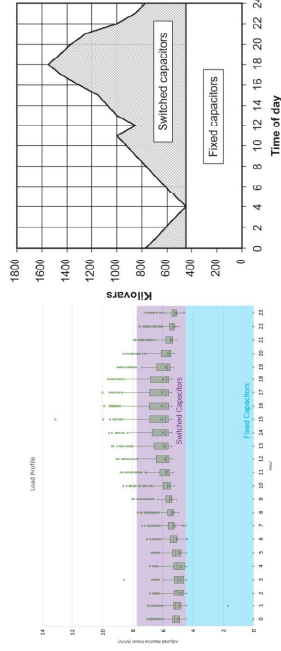
Synergi is a comprehensive power system analysis software

- Determined the time of year with max MVAR load and substation stability
- Simulated winter and summer loads
- Focused on summer for the maximum load
- Observed how recommended sizes impact the power factor (pf) and voltages

Verification showed an improved power factor and greater efficiency in delivering power to customers using the recommendation.

Results and Output

- Min CDF and the reactive power determine the fixed capacitor bank size.
- Each CDF determines the upper end of the switched capacitor bank.
- Each switched capacitor is then divided on the CDF to serve a higher likelihood of the load.
- Fit adjustments allow for manual adjustment of the PDF to allow histograms from other historical yearly data slices
- Below are our recommended capacitor bank sizes compared to IEEE 1036 [1], showing compliance with industry standards.



Next Steps, References, Acknowledgments

- Using the tool's recommendations to resize the capacitor banks at substations
- Expansion to feeder networks and line capacitors for specific reactive power correction
- Further analysis and adjusted recommendations for industrial substations
 - These do not follow any particular distribution
 - Have discrete ranges of reactive power during a year
- Integration of the tool to updated versions of the Excel software, or use of better data analysis methods such as Python or R



Student Team: Sam Han, Ethan Widger, Kyle Jeng,
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Additional Thanks: June Lukuyu, Lane Smith

[1] "IEEE Guide for the Application of Shunt Power Capacitors," IEEE Std 1036-2010 (Revision of IEEE Std 1036-1992), pp. 1-88, Jan. 2011, doi: <https://doi.org/10.1109/IEEESTD.2011.5703189>.

See 1036-199ZJ, pp. 1-88, Jan. 2011, doi:
<https://doi.org/10.1109/IEESTD.2011.5703189>.