SUBSTATION CAPACITOR BANK SIZING TOOL

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PUGET SOUND ENERGY

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

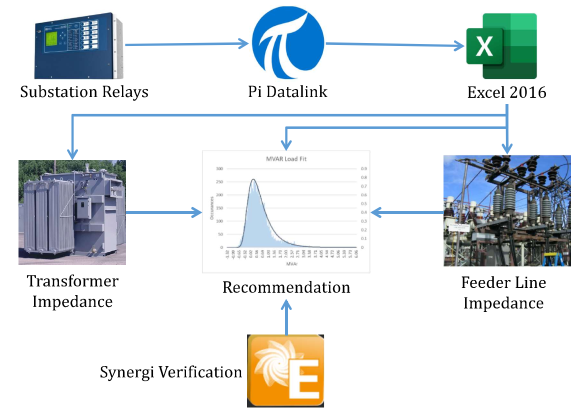
Substation Capacitor Bank Sizing Tool

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：

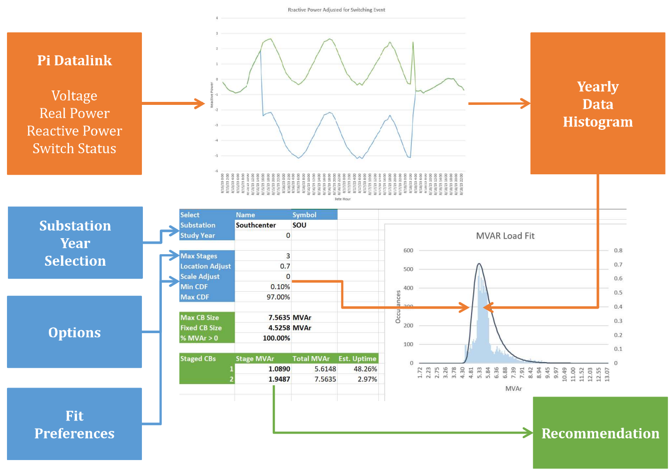
- Capable to work with Pi Datalink to retrieve substation data
- Analysis and calculations of Reactive Power (MVAR), Complex Power (MVA), Capacitor bank switch adjusted MVAr from data
- Give a result of load profile throughout the day (By 1 hour interval)
- Graph MVAR Load Fit as a result in a histogram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



Microsoft Excel Tool



Synergi Testing/Verification

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.

Before Tool Implementation:

SubTran Summary									
Sub Id	SubTran Id	Transformer Id	Feeder Id	Demand kVA	Demand % pf	Demand Amps	Demand % Ldng	Connected Customers	Connected kVA
NORTH BELLEVUE				37996	97	186	4	3757	43078
	NOB-1			22562	96	110	4	1643	21890
		NOB-1		22562	96	110	87	1643	21890
			NOB-10	111	0	5	0	0	0
			NOB-11	6877	98	311	13	63	6081
			NOB-12	6656	98	312	13	547	6417
			NOB-13	1795	98	83	3	11	1536
			NOB-14	6567	98	297	12	1022	7857
			NOB-1N	157	0	7	0	0	0
	NOB-2			15468	98	76	3	2114	21188
		NOB-2		15468	98	76	60	2114	21188
			NOB-21	3060	99	139	6	5	3519
			NOB-22	4222	99	200	8	139	5291
			NOB-23	3541	99	161	7	960	4689
			NOB-24	4395	99	207	8	1010	7688
			NOB-2N	131	0	6	0	0	0

After Tool Implementation:

SubTran Summary									
Sub Id	SubTran Id	Transformer Id	Feeder Id	Demand kVA	Demand % pf	Demand Amps	Demand % Ldng	Connected Customers	Connected kVA
NORTH BELLEVUE				37043	100	182	4	3757	43078
	NOB-1			21784	100	106	4	1643	21890
		NOB-1		21784	100	106	84	1643	21890
			NOB-10	112	0	5	0	0	0
			NOB-11	6941	98	312	13	63	6081
			NOB-12	6716	98	312	13	547	6417
			NOB-13	1812	98	83	3	11	1536
			NOB-14	6628	98	299	12	1022	7857
			NOB-1N	159	0	7	0	0	0
	NOB-2			15468	98	76	3	2114	21188
		NOB-2		15468	98	76	60	2114	21188
			NOB-21	3060	99	139	6	5	3519
			NOB-22	4222	99	200	8	139	5291
			NOB-23	3541	99	161	7	960	4689
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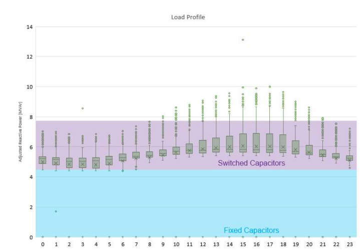
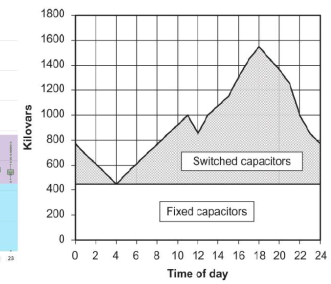
			NOB-2N	131	0	6	0	0	0

Results and Output

- Min CDF and the reactive power determine the fixed capacitor bank size.
- Max 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

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[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.

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