



Machine Learning for Optimized Chiller Staging

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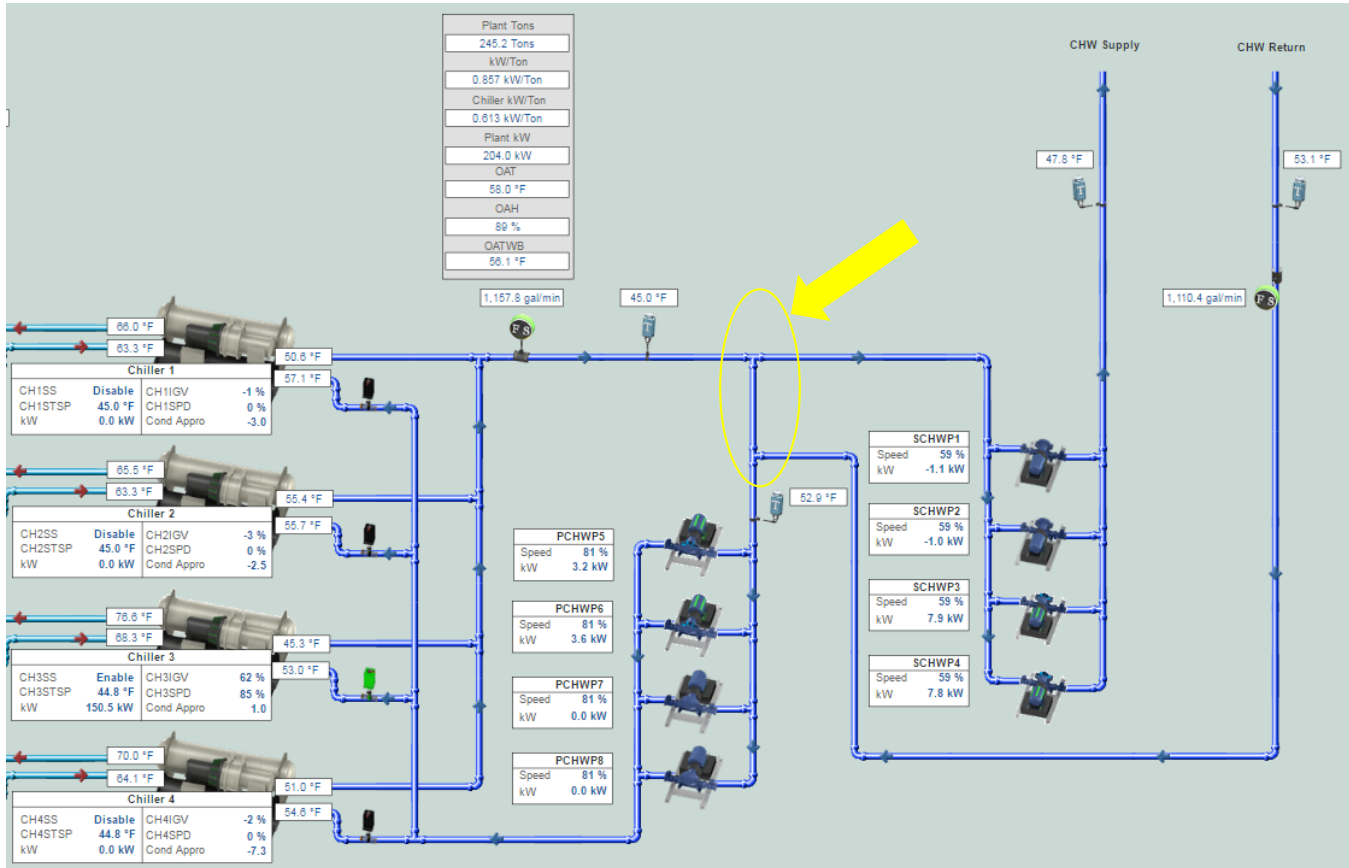
February 24, 2017

Agenda

- Traditional legacy approaches to staging chillers
- Optimized approaches to staging chillers
- Introduction to data science
- Next generation - Using machine learning for chiller staging
- Results



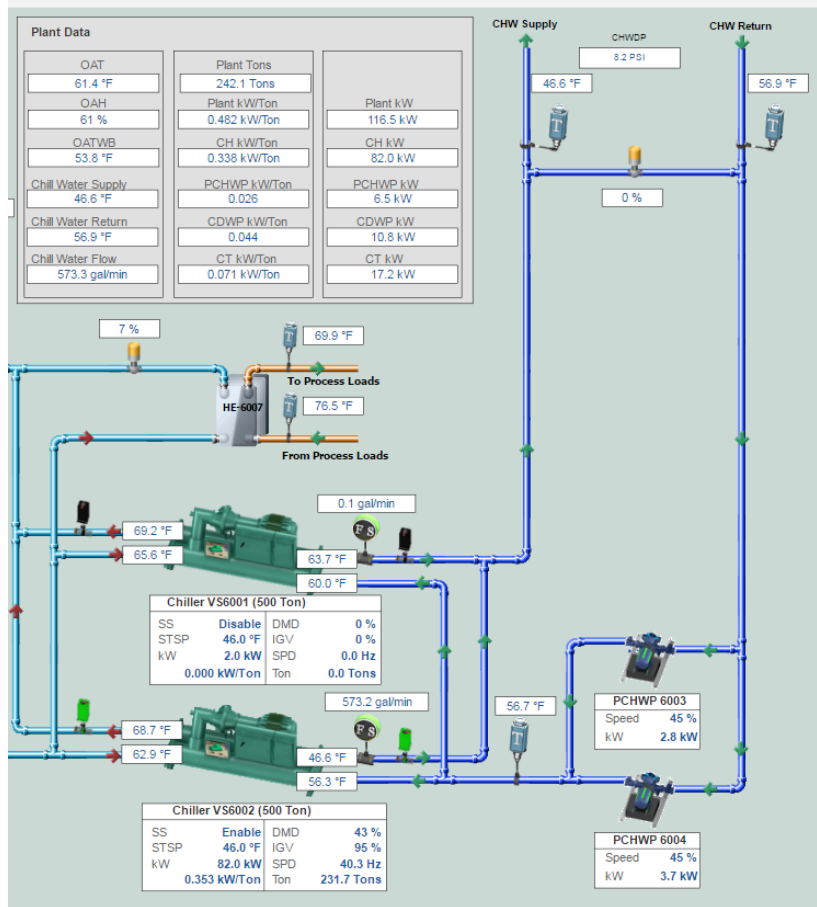
Traditional Chiller Staging: Primary-Secondary



- Decoupler flow goes negative
 - Using a gpm off-set
 - Using temperature sensor
- % amps
 - 92% amps “add”
 - 40% amps “shed”
- Equal run times



Traditional Chiller Staging: Primary-Only Systems

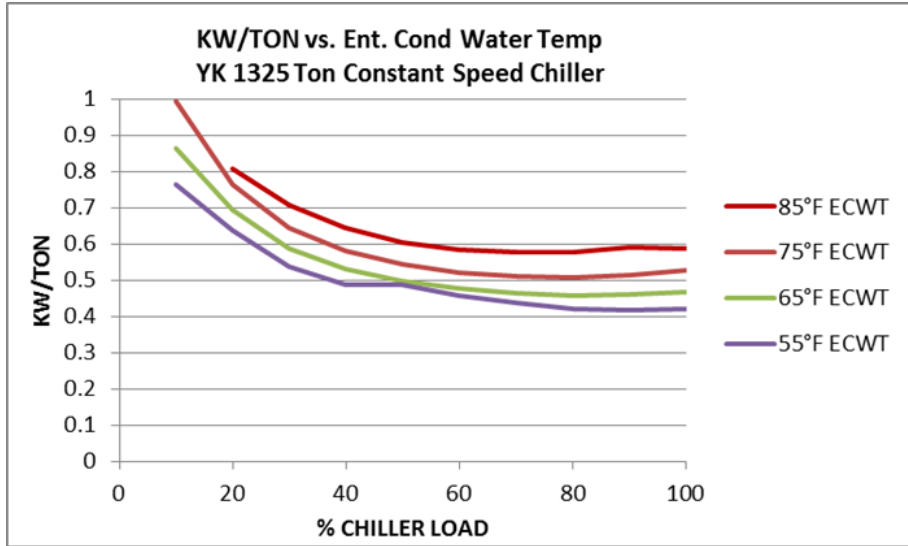


- Chilled water set point
 - > 2 deg F above set point; “add” a chiller
- Tons
 - 95% tons “add”
 - 40% tons “shed”
- % amps
 - 90% amps “add”
 - 40% amps “shed”
- Equal run times

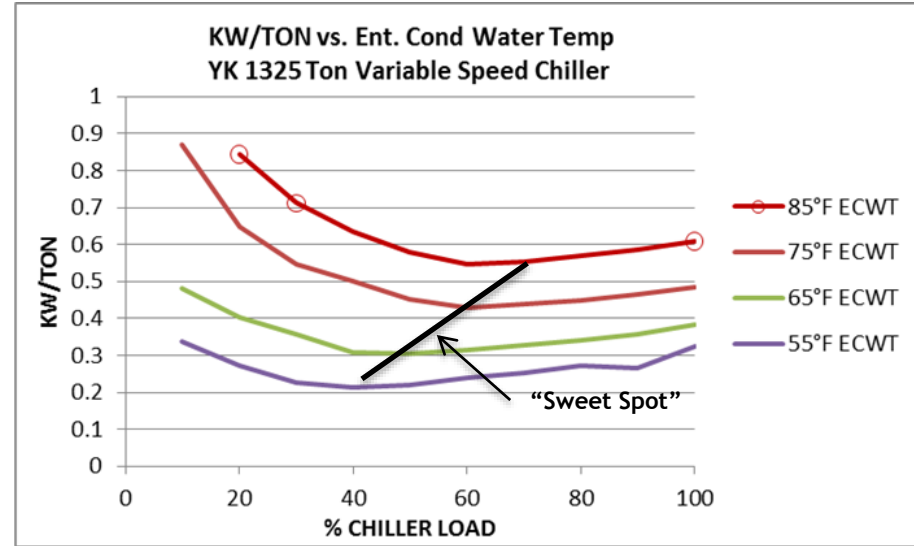


Optimized Chiller Staging

CS Chiller



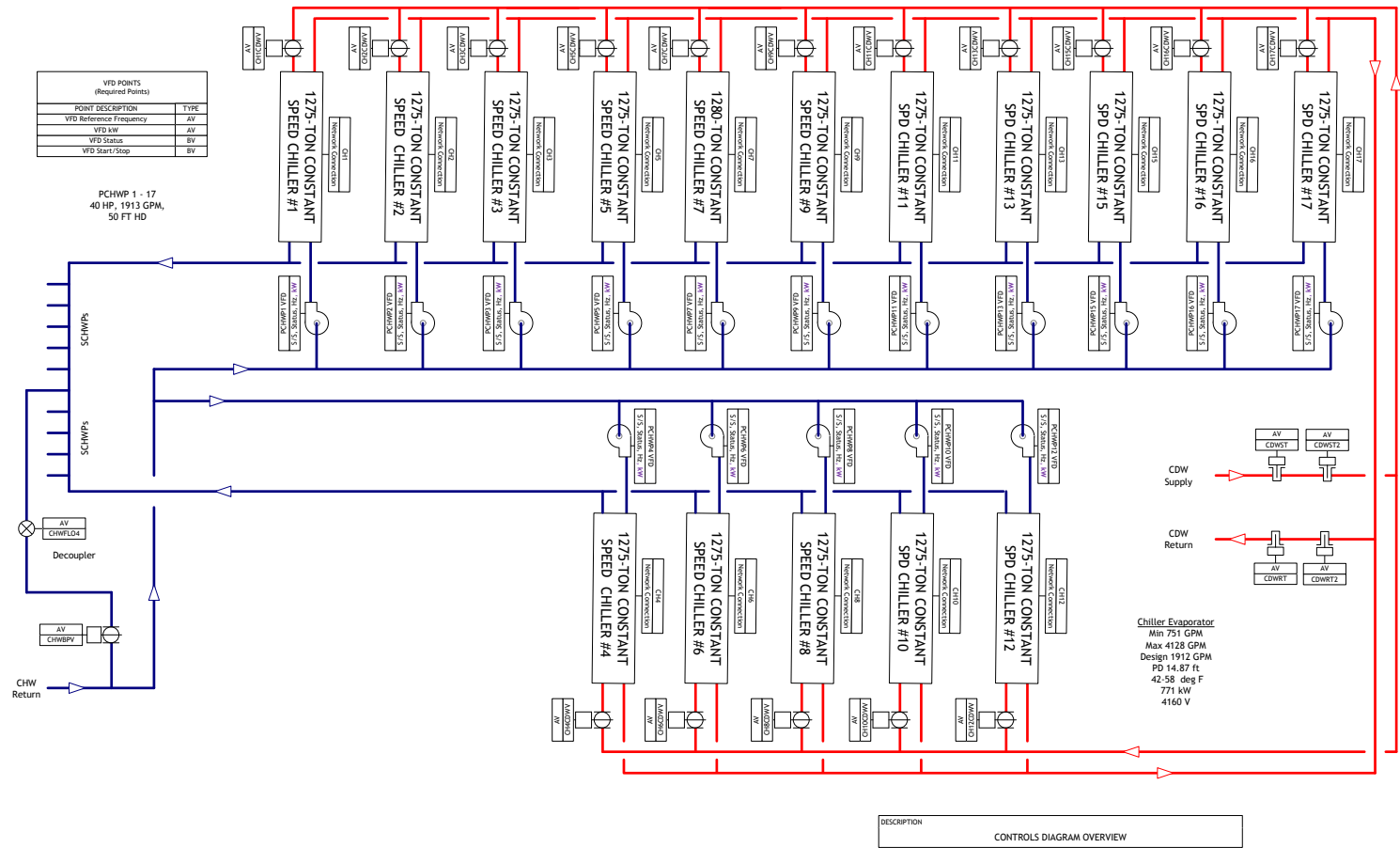
VSD Chiller



VSD chiller(s) become your lead units



District Cooling Systems - Example

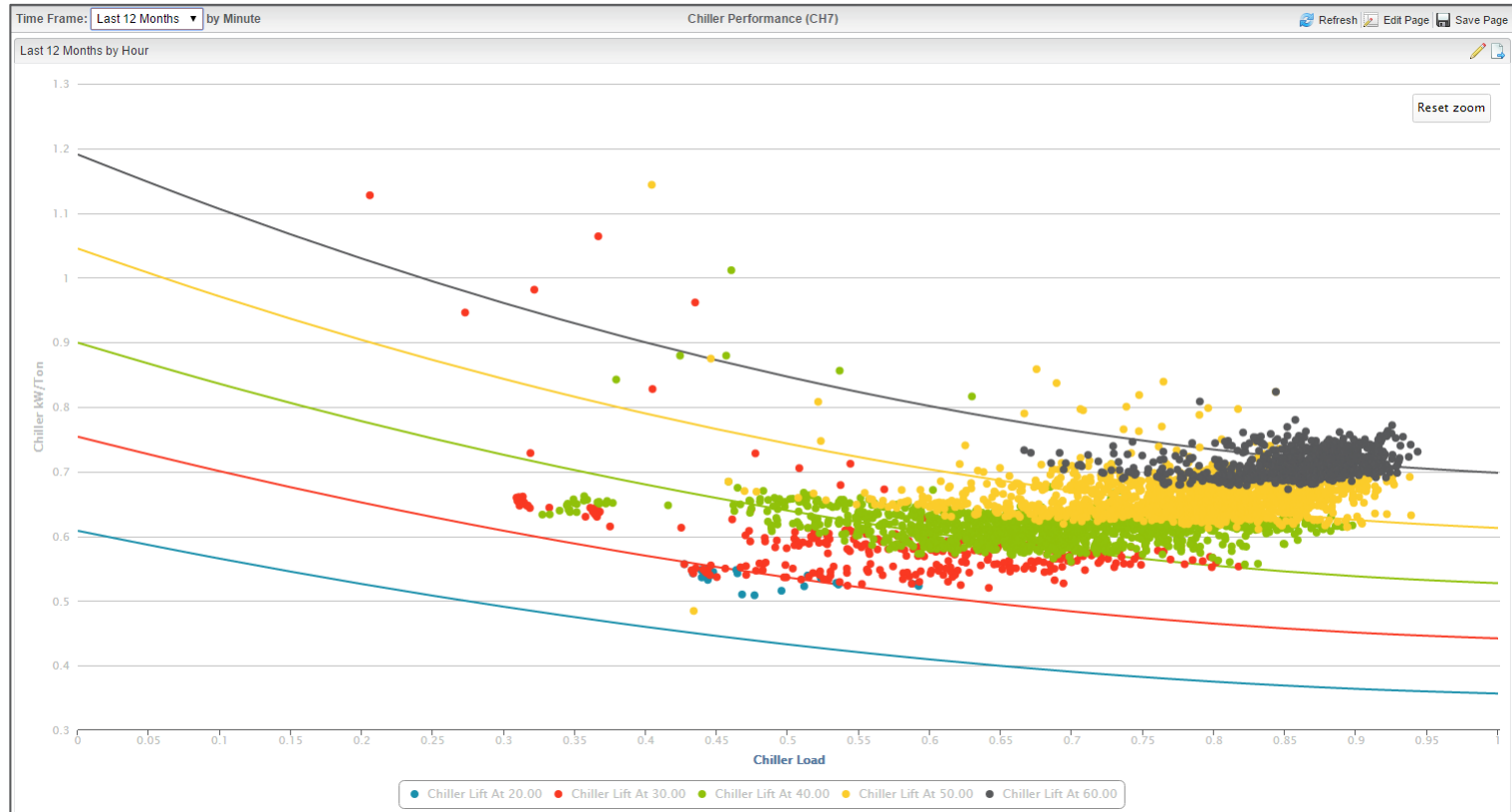


Chiller Efficiency

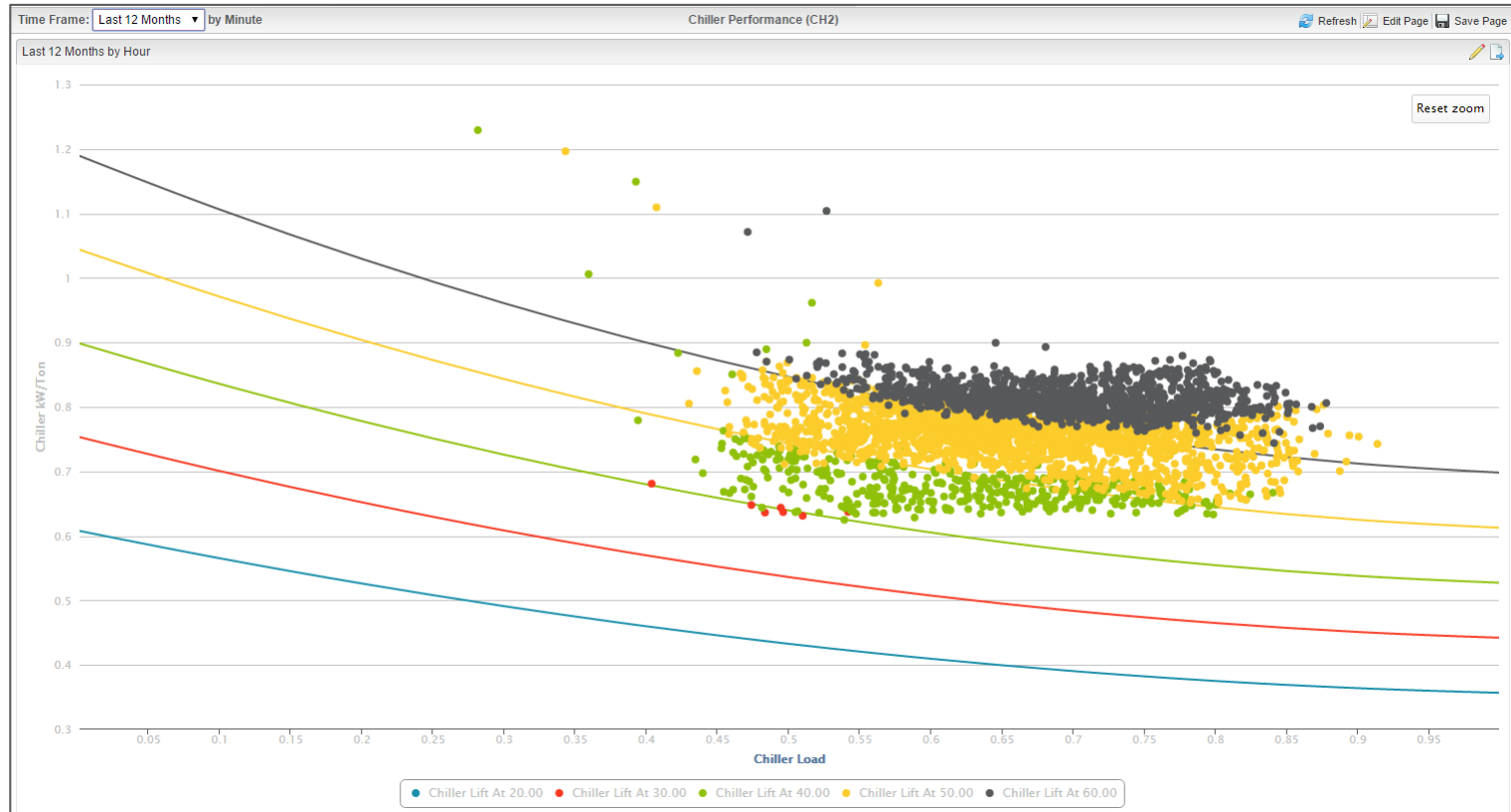
Chiller Summary (Aug 17, 2016 - Oct 17, 2016)									
Chiller	Run Hours	% Run Hours (3156 = 100%)	Avg Tons	Avg kW	Avg % CH Load	Ton-hours	kWh	kW/ton	Rank
CH1	919	29%	1179	793	64%	1,083,257	728,727	0.673	3
CH2	1096	35%	1226	967	66%	1,344,144	1,059,475	0.788	10
CH3	1056	33%	1061	801	57%	1,120,780	845,775	0.755	8
CH4	1045	33%	1399	878	76%	1,462,000	917,829	0.628	1
CH5	406	13%	1251	1069	68%	507,899	433,863	0.854	11
CH6	1397	44%	1490	1071	81%	2,081,497	1,495,548	0.718	7
CH7	638	20%	1499	1029	81%	956,651	656,793	0.687	5
CH8	321	10%	1530	1035	83%	490,995	332,373	0.677	4
CH9	301	10%	1542	1106	83%	464,270	333,002	0.717	6
CH10	150	5%	1377	1056	74%	206,548	158,461	0.767	9
CH11	1038	33%	1260	1042	68%	1,307,981	1,081,415	0.827	12
CH12	1116	35%	1557	1010	84%	1,737,863	1,127,033	0.649	2
Total	3,156		8,350	6,039		12,763,883	9,170,294	0.718	



CH-7



CH-2

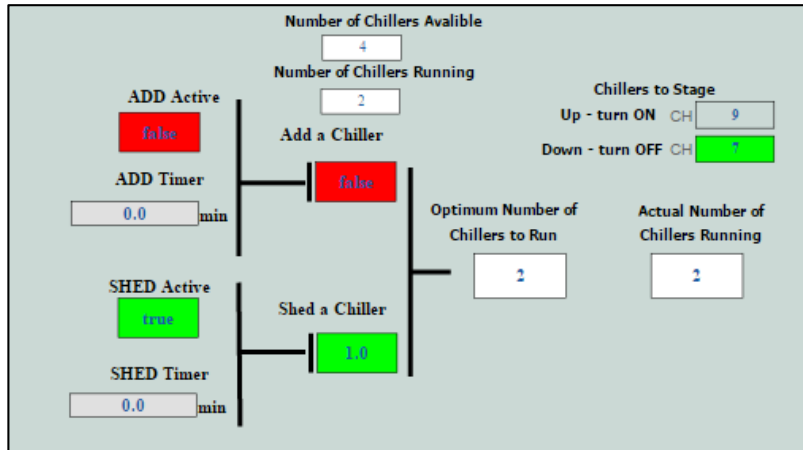


Machine Learning using the Cloud



Machine Learning for Optimized Chiller Staging

- Stage chillers based on sweat spot
- Stack rank chillers based on 60 day running efficiency
- Utilize minimum run time instead of equalized run times
- Use Dashboards to articulate direction to operators and chiller health



Staging Display

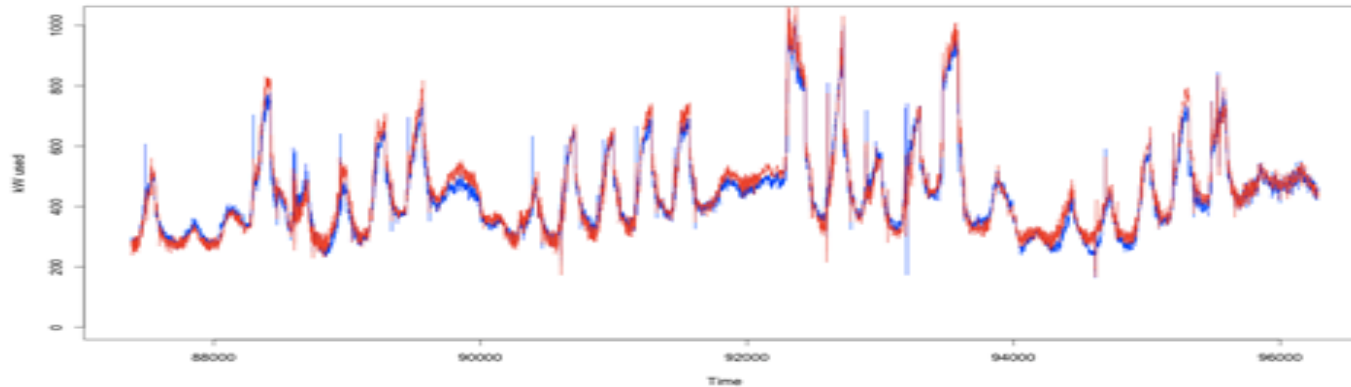
	Monthly Total/Average	Number of Rule Violations	Average When Rule Violated	Percent of Run Time When Rule Violated
Starts	2	0		
Average Condenser Approach (deg F)	4.5	125	4.9	28.87%
Average Evaporator Approach (deg F)	2.6	0	0.0	0.00%
Average Chiller VFD Speed (Hz)	52.4	0	0.0	0.00%
Average Vane Position (%)	98.6	0	0.0	0.00%
Average Discharge Superheat (deg F)	11.0	0	0.0	0.00%
Chiller Statistics				
Run Hours	598			
Average Chiller kW/ton	0.534			
Average Condenser Water Supply Temperature (deg F)	74.5			
Average Condenser Water Return Temperature (deg F)	83.9			
Average Chilled Water Supply Temperature (deg F)	45.1			
Average Chilled Water Return Temperature (deg F)	56.8			

Chiller XX Health Report



Results

- 6% energy efficiency savings over and beyond optimized staging which equates to \$100,000 to \$400,000/yr on larger district cooling sites.
- Instrumentation error - take “tons” out of the equation by using just chiller kW and outside air wet bulb



Mean absolute difference: 25 kW (5.7%)
Median absolute difference: 20 kW (4.8%)





Thank you.

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