Zero Capital Chiller
Plant and Parasitic Load Optimization

March 8, 2018
Project **Objective**

- **Identify Energy and Cost Savings Projects** at UCSF Parnassus Central Utilities Plant to Achieve UCSF energy and budget reduction goals while using limited (zero) capital
- **Provide High Impact and Low Cost Solutions** as first round of improvements while high cost capital projects are funded and planned
- **Use in-House Expertise and Existing Equipment** to limit capital costs
- **Ensure Plant Reliability and Safety** are not negatively impacted
UCSF Parnassus Campus Utilities

- Campus originated in 1896 with only 1 building
- Combined Medical, Research & Academics
- CHP Plant Commissioned in 1997

- 4 million ft² mixed space district energy system
- 14 MW Micro Grid w/ island & load shed capability
- 5,400 Tons Chilling, 120 klbs/hr Steam Capacity
Project Approach

- Complete a Full Review of Plant Equipment
  - operating performance vs design
  - control system programming and operational strategy
- Identify Opportunities
  - Potential system changes and strategies for improved controls
  - Determine expected operating efficiency improvement
- Conduct Management of Change Review
  - Ensure no impacts to equipment reliability or personnel safety
  - Ensure existing system is designed to handle the proposed changes
  - Develop operating procedures that clearly explain new operating procedure and control strategy
- Train Plant Personnel Prior to Cutover
  - Ensure operators fully understand new control strategies and operating procedures so they can recognize potential issues and act accordingly to reduce potential plant reliability issues
- Implement Changes and Monitor
  - Monitor operational and performance changes to allow further optimization
  - Maintain active and open communication with operators to help work out control issues
Identified **Plant Improvement Opportunities**

1. **Chiller Plant Optimization** - using existing VFD’s and variable system setpoints at partial loads
2. **Boiler Feedwater Pump** - energy reduction using variable pressure setpoints to capitalize on existing pump VFD
3. **Plant Ventilation System** - energy reduction using plant DCS control strategy optimization
4. **Condensate Receiver Transfer Pump** - energy reduction using plant DCS control strategy optimization
5. **HRSG’s Economizer** - efficiency performance improvement due to identified significant deterioration of efficiency from original design
Chiller Plant Optimization

- Real-time kw/ton calc to allow for easy performance evaluation and optimization
- Original pump setpoints were at chiller max design capacity. Chiller minimum design flows determined pump VFD setpoint minimums. 80% to 42% average
- Function generators to allow automated setpoint changes
- Variable condenser water temperature chiller allowed floating setpoint based on chiller load
- OAT Secondary loop DP Reset and variable chilled water temp setpoint
- Cooling tower staging based on VFD optimal performance ranges
- Cooling tower cycling at low OAT
- Tower backwash strainer pumping system optimization due to sizing for full system
Chiller Plant Optimization Results

<table>
<thead>
<tr>
<th>Average Before Optimization (kW/Ton)</th>
<th>Average After Optimization (kW/Ton)</th>
<th>Optimization Improvement</th>
<th>Annual Energy Savings (kWh)</th>
<th>Annual Operating Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.74</td>
<td>0.38</td>
<td>48.65%</td>
<td>636,254.94</td>
<td>$50,900.40</td>
</tr>
</tbody>
</table>
Boiler Feedwater Pump Optimization

- Original VFD pressure control setpoint of 290 psi was fixed to satisfy maximum HRSG feedwater flow design criteria.
- Variable pressure setpoint that follows drum pressure and steam flow of 6 drums allowed average VFD speed to go from 92% to 73% with pressure setpoint going from 290 psi to average of 242 psi.
- High select drum pressure of 6 drums with adders based on steam flow
- Built in protection to logic to revert to 290 psi anytime low drum level trip at risk
- 21% reduction in feedwater pump energy consumption
Plant Ventilation System Optimization

- Original programming always maintained all 3 generation floor exhaust fans on in low speed no matter the temperature or pressure. Temperature testing proved no concerns in running just 1 during cooler weather.
- Identified changes had been made to temperature setpoint to 75 degrees causing excessive supply fan operation. Range changed to 85-82 degrees.
- Chiller room did not have automatic programming and always ran both exhaust fans.
- Electrical room supply fans constantly ran even when it was jacket weather in room. Programing for auto start stop was added based on OAT.
- 42% reduction in plant ventilation system energy consumption.
Condensate Transfer Pump Optimization

- Original programming had transfer pump running continuously with discharge level control valve maintaining level by throttling.
- Campus condensate return level control valve was found to leak by.
- Fix of leaking control valve by re-zeroing it and adding programming to cycle pump on/off between + 6” and - 4 “ while driving level control valve to 50% allowed pump operating time to be reduced by 87% annually and reduce pump energy consumption by 72% energy annually.
Plant Parasitic Load Optimization Results

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Monthly Before (kwh)</th>
<th>Average Monthly After (kwh)</th>
<th>Optimization Improvement</th>
<th>Annual Energy Savings (kwh)</th>
<th>Annual Operating Cost Reduction ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January-10</td>
<td>646,523</td>
<td>551,036</td>
<td>14.77%</td>
<td>1,145,839</td>
<td>91,667</td>
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</table>

The graph shows the total plant parasitic load over time, with a significant reduction in monthly energy consumption.
HRSG’s Economizer Performance Restoration

- Review of HRSG Economizer performance vs. design showed significant efficiency drop in the magnitude of ~20%.
- Stack exit gas temperatures were running 50 degrees above design temperature
- HRSG overall DP was running 4” above original commissioning data causing Turbine backpressure and negative efficiency impact
- Plant logs review showed change in performance dating back 8 years
- Prior O&M provider did not inspect the economizer outlet section due to scaffolding requirement to access
- Inspection identified multiple pinhole leaks were present on the last 2 passes causing build up that blocked the fins on the top 3 passes of the 12 pass economizer
- Cleaning of the economizer section and repair of leaking tubes increased overall boiler efficiency by 3.6%. CTG efficiency improved by an average of 0.7% due to reduced backpressure on turbine exhaust.
HRSG #1 Economizer Tubes

Before Cleaning

After Cleaning
HRSG #2 Economizer Tubes

Before Cleaning

After Cleaning
## HRSG’s Economizer Performance Improvement

### Economizer Repair/Cleaning Savings

<table>
<thead>
<tr>
<th>GTG Performance Improvement</th>
<th>HRSG/GTG #1</th>
<th>HRSG/GTG #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRSG Overall Diff Pressure Before Cleaning</td>
<td>11.7</td>
<td>11</td>
</tr>
<tr>
<td>HRSG Overall Diff Pressure After Cleaning</td>
<td>7.6</td>
<td>7.3</td>
</tr>
<tr>
<td>GTG Average Heatrate 52-65 degrees Before Cleaning (BTU's/kWh)</td>
<td>11,962</td>
<td>12,259</td>
</tr>
<tr>
<td>GTG Average Heatrate 52-65 degrees After Cleaning (BTU's/kWh)</td>
<td>11,917</td>
<td>12,137</td>
</tr>
<tr>
<td>Heatrate Improvement (BTU's/kWh)</td>
<td>45</td>
<td>122</td>
</tr>
<tr>
<td>Natural Gas Therms Saved Per Year</td>
<td>19,718</td>
<td>53,780</td>
</tr>
<tr>
<td>Annual Operating Cost Savings</td>
<td>$12,028</td>
<td>$32,806</td>
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### HRSG Performance Improvement

<table>
<thead>
<tr>
<th>GTG Exhaust Heat Transferred Before Economizer Cleaning (BTU's/hr)</th>
<th>25,641,183</th>
<th>27,317,736</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTG Exhaust Heat Transferred After (BTU's/hr)</td>
<td>27,122,262</td>
<td>29,031,043</td>
</tr>
<tr>
<td>Boiler Efficiency Improvement</td>
<td>3.44%</td>
<td>3.81%</td>
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<tr>
<td>Natural Gas Therms Saved Annually</td>
<td>153,411</td>
<td>160,317</td>
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<tr>
<td>Annual Operating Cost Savings</td>
<td>$93,580.98</td>
<td>$97,793.60</td>
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**Total Annual Operating Cost Savings** $236,208.71
Project Summary and Lessons Learned

- Original equipment control logic programming may have significant room for improvement toward efficiency gains through low cost in house programming efforts.
- Without periodic re-commissioning of systems, performance can change due to changes in the operation or the equipment health.
- Systems are often originally designed and programmed to match full load needs with little effort to provide programming to take advantage of partial load opportunities.
- Total Annual Electrical Savings = 1,780,000 kwh
- Total Annual Gas = 314,000 Therms
- Total Annual Operating Budget Improvement = $379,000
- Total Capital Cost = $0