Automated Chiller Demand Control

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Introduction to NYULH

- 3.6 M SQFT Main Campus.
- Centralized Steam and CHW systems
- 2 CHPs – Primary 7 MW Gas Turbine w/ 2.4 MW Steam Turbine combined cycle
- Secondary 2.9 MW reciprocating gas engine CHP (in progress)
- 3 Electric + 1 Steam Turbine Chiller Plant feeding single loop
NYU Langone Health Energy Timeline

1980s
Campus converts from stand alone to distributed chilled water distribution
Skirball Building and Electrical Centrifugal Chiller Plant is constructed

2007
NYULH Energy Management Program begins with hire of John Bartlik
Smilow Building & Electrical Centrifugal Chiller Plant opens
New Tisch Steam Turbine Chiller Plant is built

2012
Construction of Energy Building begins
Hurricane Sandy causes extensive damage

2013
Construction of Kimmel Pavilion and Science Building begin along with Campus Restoration.

2016
CHP Gas Turbine start-up
30% carbon reduction goal achieved

2018
Kimmel Pavilion & Science Building opens
Kimmel Chiller Plant opens
NYULH achieves USGBC Peer Platinum certification
$100M total energy savings achieved
NYULH Campus

KIMMEL CHILLERS
- 5 x 1,360 Ton York Electric
- 1 x 400 Ton York Electric
- 1,400 Tons Plate & Frame
- Primary Electrical Service Tariff
- Daily Demand
- Demand Cost (Summer): $0.8335/kW/day
- Demand Cost (Non-Summer): $0.4521/kW/day
NYULH Campus

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TISCH CHILLERS
• 3 x 2,000 Ton York Steam Turbine
• Electrical Centrifugal
• 800 Tons Plate & Frame
• Primary Electric Service Tariff
• 100% Cogen → 100% Duct Fire
• ~ 9 lbs Steam/Ton Hour = ~1.3 COP
• Cost: $.044/Ton Hour year round due to fixed gas price
NYULH Campus

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SKIRBALL CHILLERS
- 3 x 1,200 Ton York Electric, 1 w/VFD
- Electrical Centrifugal
- Secondary Electrical Service
- Daily Demand
- Demand Cost (Summer): $1.52/kW/day
- Demand Cost (Non-Summer): $.7577/kW/day
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SMILOW CHILLERS
- 3 x 1,200 Ton York Electric Chillers
- Electrical Centrifugal
- Secondary Electrical Service w/ kWh T&D
- Monthly Demand
- Demand Cost (Summer): $40/kW/month
- Demand Cost (Non-Summer): Plant Not Used

SKIRBALL CHILLERS
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- Electrical Centrifugal
- Secondary Electrical Service
- Daily Demand
- Demand Cost (Summer): $1.52/kW/day
- Demand Cost (Non-Summer): $.7577/kW/day
Past Challenges

• **Chilled water plants operated in parallel**
  – Chilled water pump speed controls based upon differential pressure at plant wall. No end of line sensing.
  – Differential pressure controls in parallel pump control caused minimum flow control issues and chiller trips.
  – Due to issues with reliability operating in parallel, plant operators would isolate the plants and lose fuel source flexibility, decrease efficiency of chillers.

• **Operators Issues:**
  – Personal preference on how to run their plant creating additional demand charges and excessive steam use.
  – Misguided operation of plant to design values (e.g. always running at design CW temp).
Requirements for Chiller Dispatch

- Use lowest cost chiller at all times
- Easy procedure for operators to understand
- Highly automated
- Ensure adequate flow in all parts of campus
- Avoid unnecessary demand exceedances
  - Monthly Demand In Smilow Plant
  - Daily Demand Kimmel/Skirball Plants
System Layout

TISCH CHILLERS SPECS
- 3 x 2,000 Ton York Steam Turbine
- Primary Electrical Service

SMILOW CHILLERS SPECS
- 3 x 1,200 Ton York Electric Chillers
- Secondary Electrical Service

KIMMEL CHILLERS SPECS
- 5 x 1,360 Ton, 1 x 400 Ton York Electric
- Primary Electrical Service

SKIRBALL CHILLERS SPECS
- 3 x 1,200 Ton York Electric, 1 w/ VFD
- Secondary Electrical Service
1) Determine Minimum DP Set Point

Sets Point

max

min

max

min

Outside Air Enthalpy

<table>
<thead>
<tr>
<th>DP Sensor</th>
<th>DP SP</th>
<th>DP ERR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP 1</td>
<td>DP 1 SP</td>
<td>DP ERR 1</td>
</tr>
<tr>
<td>DP 2</td>
<td>DP 2 SP</td>
<td>DP ERR 2</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>DP 10</td>
<td>DP 10 SP</td>
<td>DP ERR 10</td>
</tr>
</tbody>
</table>

Establishes the minimum DP SP required at strategic locations in the system and determines a worst case error, lowest DP relative to its SP, to be used to control total plant flow output.

2) Determine PID Output for Worst Case Error

<table>
<thead>
<tr>
<th>DP Sensor</th>
<th>DP SP</th>
<th>DP ERR</th>
<th>PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP 2</td>
<td>DP 2 SP</td>
<td>DP ERR 2</td>
<td>73%</td>
</tr>
</tbody>
</table>

The PID output represents the percentage between each chiller’s minimum and maximum allowable flowrate.

3) Determine GPM of Each Chiller Plant

Each plant’s chilled water pumps operate to maintain their respective plant GPM SPs. This initial SP is subject to limits based upon plant KW, chiller capacity and load balancing.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Chiller</th>
<th>DP SP</th>
<th>Pump Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tisch</td>
<td>CH 1</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Tisch</td>
<td>CH 2</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Tisch</td>
<td>CH 3</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Kimmel</td>
<td>CH 4</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Kimmel</td>
<td>CH 9</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Kimmel</td>
<td>CH 10</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Skirball</td>
<td>CH 11</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Skirball</td>
<td>CH 12</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Smilow</td>
<td>CH 13</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Smilow</td>
<td>CH 14</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
<tr>
<td>Smilow</td>
<td>CH 15</td>
<td>GPM SP</td>
<td>Total GPM SP</td>
</tr>
</tbody>
</table>
Chiller Curtailment Controls

1. **Electrical Service kW Curtailment** – Limit demand cost

2. **Chiller Capacity Control** – Prevents overload and temperature loss

3. **Electric Chiller Plant Load Balancing** – Maximize efficiency
OFF-PEAK OPERATION

GPM Set Point Curtailment
1. kW Control
2. Capacity Control
3. Load Balance

Time of Operation:

Hourly Tonnage Distribution

On-Peak Operation
ON-PEAK EARLY OPERATION

GPM Set Point Curtailment
1. kW Control
2. Capacity Control
3. Load Balance

Time of Operation:

Hourly Tonnage Distribution

On-Peak Operation
ON-PEAK OPERATION

GPM Set Point Curtailment
1. kW Control
2. Capacity Control
3. Load Balance

Time of Operation:

Hourly Tonnage Distribution

On-Peak Operation
Benefits

• Consistent operations
• System reliability
• Reduced plant trips
• Automation reduces operator error
• Enhanced energy, carbon, and cost savings
Maximizing Cost Reduction
Pre-CHP Chiller Dispatch Model

Cost vs. Savings

Net Savings

Tonnage Profile

Cumulative Net Unit Cost
(steam vs. electric)

KW Savings

Max Savings

Tonnage Cap

Tons

Time

Net Savings

Cost vs. Savings

Tonnage Cap

Cost vs. Savings

Tonnage Cap
In all cases, cutoff should be where marginal demand savings is less than marginal cost of fuel switch.
Pre-CHP Chiller Dispatch Model

Demand is a sunk cost. Running more hours below peak reduces cost per hour.
# NYULH Utility Rate Changes

<table>
<thead>
<tr>
<th>Utility</th>
<th>Old Model</th>
<th>New Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric</strong></td>
<td>Flat rate commodity, monthly demand, variable T&amp;D.</td>
<td>Floating commodity, primarily contract and as-used daily demand (no ratchet), no T&amp;D. Virtual offset of other accounts.</td>
</tr>
<tr>
<td><strong>Natural Gas</strong></td>
<td>Minimal Use (Kitchen Only)</td>
<td>Fixed price firm for CHP, market price IT for boilers</td>
</tr>
<tr>
<td><strong>District Steam</strong></td>
<td>Primary heat source. High unit cost, monthly demand in winter only.</td>
<td>High contract demand, reduced rates, tertiary backup only.</td>
</tr>
<tr>
<td><strong>Chillers (Steam &amp; Electric Drive)</strong></td>
<td>Lead with electric, peak shave with steam.</td>
<td>Dispatch strategy varies.</td>
</tr>
</tbody>
</table>
Keys for Developing Dispatch Plan

• Electric costs vary tremendously, marginal unit costs are key

• Steam chilling is *usually* more expensive than electric when demand is ignored, but a cost effective demand reduction method.

• Once a demand threshold is hit, it has no additional marginal cost:
  – Limit monthly demand (at Smilow) for predicted monthly peak. Goal is to max out all other plants
  – Limit daily demand for predicted daily peak
At beginning of month, it was estimated that monthly peak load would require 1 Smilow Chiller with all other plants at max. Thus, 1 Smilow chiller is run at all times during 8A-10P demand peak to reduce daily demand in other plants as the monthly demand is a sunk cost.

Predicted peak load is 12,000 tons. At peak of day, optimal conditions are:
- 6,000 tons (full capacity) from Tisch Steam Plant
- 1,200 tons from Smilow Electric Plant (limited to monthly peak)
- 4,800 tons from Kimmel Electric Plant

Set limit in Kimmel to estimated KW at 4,800 tons
Example Daily Operation

Hourly Tonnage Distribution

- Electric plants offload automatically as base building KW increases.
- Skirball plant needed to maintain load - 600 ton min capacity.
- Slight curtailment of Smilow to offset base building peak.
- Steam Plant still peaks at overall daily peak.

Smilow Tons (Monthly Demand)
Skirball Tons (Daily Demand)
Kimmel Tons (Daily Demand)
Tisch Tons (Steam)
Example Daily Operation – High Demand Day

Hourly Tonnage Distribution

- **Smilow Tons (Monthly Demand)**
- **Skirball Tons (Daily Demand)**
- **Kimmel Tons (Daily Demand)**
- **Tisch Tons (Steam)**

### Example Daily Operation

- **High Demand Day**

  **Kimmel Plant KW setpoint raised to max.**

  **Skirball** now offloads automatically as base building KW increases.

  **Steam Plant still peaks at overall daily peak.**

- **Skirball** picks up balance of off-peak capacity.
Marginal Cost Changes

Marginal Costs - Typical Day

Marginal Costs - High Cost Day

Steam Unit Costs
Lowest – Steam Lead Mode
Total Cost Profile

Total Cost w/ Daily Demand - Typical Day

Total Cost w/ Daily Demand - High Cost Day
## Operator Management

### Chiller Dispatch Sequence: STEAM LEAD

1. **Utilize Free Cooling**
   - Operate Kimmel and/or Tisch

2. **Baseline Steam Chillers**
   - Fully load steam chillers before electric chillers

3. **Operate Electric Chillers**
   - Chiller operating range to be maintained between 50% - 70% PAU under normal conditions. Max KW SPs are not to be exceeded.

4. **Skirball**
   - Operate: Remaining chillers, exceeding KW

5. **Smilow**
   - Operate: Remaining chillers, exceeding KW

**Increasing Chilled Water Load**

### Chiller Operation Notes

- **Kimmel** is the preferred electric plant, so it should be operated, as the load requires, up to its current demand setpoint (SP) at all times.

- **Skirball** is the next preferred electric plant after Kimmel to operate so it should be operated, as the load requires, up to its current demand setpoint (SP) at all times.

- **Smilow** is used to fill in the load that the Kimmel and Skirball plants cannot deliver in conjunction with the steam chillers operating at minimum flow setting. Run as required to maintain minimum pressure at end of loop.

- The Smilow demand is set monthly at or around the 24th of the month. If chilled water load increases while Skirball and Kimmel are either off or curtailed, load Smilow as required up until it begins curtailing at KW SP.

### Operator Notes

- **Kimmel** if all Tisch chillers are operating at full capacity and the 3 electric plants are curtailed, Kimmel will be the first plant to be allowed to run through its demand setpoint.

- **Skirball** should be the second plant to be allowed to run through its demand setpoint.

- Always ensure that Kimmel, Skirball, and Tisch are fully loaded before allowing Smilow to exceed its demand setpoint. If necessary, shutdown a Smilow chiller to reduce building demand before exceeding setpoint.
Next Steps

• **Fan energy reduction program**
  – When steam chilling is available, lower AHU discharge temperature
  – This will cause VAVs to close, reducing fan speeds
  – Spaces will be maintained with less cooler air

• **Advanced submetering & machine learning program**
  – Submetering of each individual buildings
  – Machine learning to predict KW, CHW, and Steam loads
  – Will allow for more accurate KW setpoints
Thank You