T11 - Central Utilities Optimization
Chiller and Pumping Solutions

Overview

Chilled Water Systems

How We Can Help

Questions
Classifying

Industrial Chillers

Centralized
- serves multiple cooling needs
- capacities range from ten tons to hundreds or thousands of tons

Decentralized
- each application or machine has its own chiller
- small capacity: from 0.2 tons to 10 tons

Combination
- for plants with cooling requirements the same for some applications or points of use, but not all
Chiller Staging and Chilled Water Loops

- Very seldom will you find one chiller for an entire facility
  - Back-up units at a minimum
  - Usually staging to have capacity meet demand

- Chiller Staging: Using multiple chillers to match supply of chilled water to facility demand

- Chilled Water Loop: Provides chilled water to facility and returns water back to chiller system. Always includes some form of bypass to allow more efficient operation during changing demands
  - Primary loop provides direct flow of chilled water to plant
  - Primary-Secondary loop manages fluctuations in facility without rapid changes chiller staging
Chiller Loop: Primary-Only vs. Primary-Secondary

Advantages of Primary-Only
- Lower up front cost
- Less plant space required
- Reduced pump peak power
- Lower pump annual energy usage [w/Variable Frequency Drives (VFDs) on infeed]

Disadvantages of Primary-Only
- Complexity of bypass control
- Complexity of staging chillers
Chilled Water System
## Applications & Industries Used

<table>
<thead>
<tr>
<th>Plastic Industry: Injection and Blow Molding</th>
<th>Paper and Cement Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Working and Cutting Oils</td>
<td>Vacuum Systems</td>
</tr>
<tr>
<td>Welding Equipment</td>
<td>X-ray Diffraction</td>
</tr>
<tr>
<td>Die-casting and Machine Tooling</td>
<td>Power: Supplies, Generation Stations</td>
</tr>
<tr>
<td>Chemical Processing</td>
<td>Analytical Equipment</td>
</tr>
<tr>
<td>Pharmaceutical Formulation</td>
<td>Semiconductors</td>
</tr>
<tr>
<td>Food and Beverage Processing</td>
<td>Compressed Air and Gas Cooling</td>
</tr>
</tbody>
</table>

They are also used to cool high-heat specialized items such as MRI machines and lasers, and in hospitals, hotels and campuses.
Chillers And Terms

- Terminology
- How It Works
Chiller Terminology

- **Tons:** One ton of cooling is the amount of heat absorbed by one ton of ice melting in one day, which is equivalent to 12,000 Btu per hour (h), or 3.516 kilowatts (thermal).

- **Air-Conditioning, Heating, and Refrigeration Institute (AHRI):** A manufacturer trade organization which certifies chiller performance according to its Standard 550/590-2003: Performance Rating of Water-Chilling Packages Using the Vapor Compression Cycle. Various efficiency metrics are commonly used for chillers.

- **Full-load efficiency:** This metric is the efficiency of the chiller at peak load and at AHRI standard conditions, measured in kilowatts (kW) per ton. This metric is a specific case of the broader metric, power input per capacity—sometimes called the “kW/ton rating”—which can be measured at any given set of rating conditions. A lower kW/ton rating indicates higher efficiency.

- **Part-load efficiency:** This is the efficiency of the chiller at part load, measured in kW/ton by either integrated-part load value (IPLV) or nonstandard part-load value (NPLV), depending on the particular AHRI part-load test conditions. Both give the efficiency of the chiller averaged over four operating points according to this formula:

\[
A = \text{kW/ton at 100 percent load}, \quad B = \text{kW/ton at 75 percent load}, \quad C = \text{kW/ton at 50 percent load}, \quad D = \text{kW/ton at 25 percent load}
\]
How It Works

*Industrial chillers typically come as complete, packaged, closed-loop systems including:*

- Chiller unit
- Cooling Tower
- Pumping station with recirculating pump

*Location of Industrial Chillers*

- Commonly located in mechanical equipment rooms within the building close to the process in which they are cooling
- Directly beside the process – depending on the size of the chiller and compressor
- Outdoors
How It Works – Controlling Temperature

- Water flows from the chiller to the application's point of use and back.
- A Storage tank can help maintain chilled water temperature and prevents temperature spikes from occurring.

- Chilled water does not go directly from the chiller to the application, but to an external storage tank which acts as a sort of "temperature buffer."
- Chilled water goes from the external tank to the application, and the return warmer water from the application goes back to the chiller.
Refrigerant chillers use vapor compression, which has four main steps:

1) Compression (compressor)
2) Condensing (condenser)
3) Expansion (expansion valve)
4) Evaporation (evaporator)
Chiller Dispatch Systems

Global Solutions

PUBLIC INFORMATION
Why Focus On Chillers?

**Chillers are one of the larger horizontal (across all industry verticals) unit operations / process equipment skids**

- Plant Utilities: Almost every type of facility requires chillers for process equipment cooling and cold air / dehumidifying and cold water
- Most chillers currently leverage proprietary controls w/VFDs
  - Customers want better diagnostics & information – ripe for control focus as part of plant-wide control
- Significant global increase in the amount of chilled water required
- Major focus on reducing energy usage
- Large installed base with mature control systems on them.

![Process Industry Segmentation](image)
Chiller Dispatch Key Concepts

- To Add a Chiller (3) Conditions must be met:
  - Chiller Load is at maximum
  - Chiller Evaporator Flow at maximum
  - Evaporator Temperature deviation from set point
  - Start / Stop Timer – above conditions must be met

- To Stop a Chiller
  - Chiller at minimum Evaporator Flow
  - Chiller Load is at minimum load
  - Start / Stop Timer – above conditions must be met

Goal - Minimize Consumption & Maximize Output
Condenser Water Pumping

The setpoint to the Master CW Pump Controller is based on sum of the water required to operate the following:
- Chillers Commanded to Run
- CW - Total Condenser Water Flow through Running Chillers

O-Operator P-Program

DEMAND - 2
- CW Pump #1: Operator P 0 0 3 2.2 Hrs
- CW Pump #2: Operator P 0 2 26.8 Hrs
- CW Pump #3: Operator P 0 4 24.0 Hrs
- CW Pump #4: Operator P 0 1 10.7 Hrs

Distribution Header Flow Rate: 15000.0 GPM
Pumps Bank dP: 20.00 PSID

Running Pumps: 1 2 3 4

System Efficiency: 8.7 KWh/GPM
System Power: 94.4 KW
Total Pump Current: 390.8 AMPS

Master CHW Pump Controller Load
○ Low
○ High

Condenser Water From Towers

Condenser Water Pump Dispatch Countdown: 30 sec

Demand

OOS

Running Forward

Stopped

Running Forward

stopped

System Efficiency: 8.7 KWh/GPM
System Power: 94.4 KW
Total Pump Current: 390.8 AMPS

City Water Makeup

Valve Control

Closed

Valve Control

Closed

4

2

3

1

11/1/2012 12:56:14 AM
11/1/2012 12:55:59 AM

Connection to controller DPC11 has been lost (Server: RNA://SLocal/Demo DPC11...
Connection to controller New_Shortcut has been lost (Server: RNA://SLocal/Demo DPC11...
Centrifugal Pump Optimizer
External Presentation

Name - Arial Narrow 16pts
Title - Arial Narrow 16pts
Date - Arial Narrow 16pts

PUBLIC INFORMATION
Providing Energy Optimization to Pumping Applications

**Common Competitor Solutions**

**No Optimization Control**

- Across the line starters / soft starters with control valve
- Lead/lag control or synchronized pumps based on load
- Limited to non-existing diagnostics
- Limited to non-existing system configuration
- Limited to non-existing communications

**Rockwell Automation Packaged Solutions**

- Pre-programmed assembly of Rockwell Automation control system architecture
- Pump optimization control- dispatch optimal number of pumps to reduce energy
- PanelView™ HMI simplifies operator interface
  - Extensive diagnostics
  - Complete system configuration
- Easily integrated into a plant-wide network
Centrifugal Pump Optimization Principle

- Customers “typical” Variable Frequency Drive (VFD) / pump dispatch (lead/Lag)
  - Turn on the 1st pump, run it up to 90 – 100% of the VFD capacity
  - Turn on the 2nd pump…
  - And so on…
  - This dispatch method does not take the full advantage of the energy savings of having multiple VFD’s and pumping affinity laws

- Additional energy savings can be realized using the Rockwell Automation pump optimizer in centrifugal pumping configurations by:
  - Dispatching pumps based on:
    - Pumping affinity laws
      - A small reduction in speed equals a large reduction in power consumption
    - Efficiency curves

- For example, it may be more energy efficient to run 2 pumps at 45% speed rather than 1 pump at 90% speed to meet the required flow based on the pump affinity laws & efficiency curves
Centrifugal Pump Optimization Savings

- The algorithm behind the pump optimization control system calculates the shaft power usage by taking into account pump, motor and variable frequency drive efficiencies at the real time monitored system flow and head conditions.

- The final shaft power values are compared for the various pumping configurations and the lowest power usage scenario is selected.

- The required numbers of pumps in the lowest power usage scenario are commanded to run by the system.

- For example, using the pump optimization control algorithm on a pumping system with four 600 HP & 250HP pumps saves the following energy compared to other standard industry control techniques.

Assumptions:

- Typical flow distribution
- Cost of $0.07/kWh
- Utilizing VFDs

Savings will be substantially higher if system being replaced is not utilizing VFDs.

Note: Many factors affect energy savings, this figure should only be used as one form of estimating, estimated savings are not guaranteed. **
The Rockwell Automation Centrifugal Pump Optimizer

Optimizer for applications with centrifugal pumps in parallel with common supply/discharge header configuration

- Key features:
  - CompactLogix™ L33ER controller
  - 15”PanelView™ Plus 15” HMI color display
  - Easy to use PlantPAx® faceplates
  - Supports up to 6 pumps in parallel
  - Connection to VFDs and instruments
    - Hardwired or via communications
      - Ethernet & serial – standard
      - BacNet/IP, Modbus TCP/RTU - available
  - Two levels (base & enhanced)
    - Customization available via Global Solutions
Centrifugal Pump Optimizer

- Convenient NEMA enclosure, terminations & power supplies
- Better Visibility
  - Full graphical interface
- Advanced Control Features
  - Advanced control based on load curves and affinity laws
  - Allow for lead/lag control
  - Standard CompactLogix hardware
  - Based on commercial off-the-shelf technology

HMI application
Easy System Configuration

- Pump data for optimizer calculations
- Communication – hardwired/softwired
  - Instrumentation
- VFD
  - Interlocks/permissives
- Pump rotation / pump priority
- Pump optimizer or lead/lag control
- Operator / program mode

_Eliminates need for engineering PLC Configuration_
System Diagnostics

Extensive system diagnostics

- Easily view complete system health and statuses
- Alarm storage & management with timestamps
- Network health
- IO health
- Trending signals

Eliminates need for engineering PLC configuration
Large Food Manufacturer
Centrifugal Pump Optimizer Solution

57% Energy reduction by optimizing dispatch of pumps on high pressure hardware system

<table>
<thead>
<tr>
<th>CHALLENGE</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Abnormally high energy bills when not in production</td>
<td>• Solution delivery/execution description:</td>
</tr>
<tr>
<td>• Control high pressure hot water pumping system</td>
<td>• Deployed submeters to measure current state</td>
</tr>
<tr>
<td>• 4 x 475 Hp Centrifugal Pumps in parallel</td>
<td>• Pump Solution Kit</td>
</tr>
<tr>
<td>• Manual intervention was not practical</td>
<td>• Standard code loaded onto predesigned panel</td>
</tr>
<tr>
<td></td>
<td>• VFDs spec’d by Rockwell Automation and bundled into sale</td>
</tr>
<tr>
<td></td>
<td>• PanelView™ Plus displays system status</td>
</tr>
<tr>
<td></td>
<td>• Dispatch equipment energy efficiently</td>
</tr>
<tr>
<td></td>
<td>• System uses same HW/SW as production areas</td>
</tr>
<tr>
<td></td>
<td>• Easily integrates into the corporate energy system</td>
</tr>
</tbody>
</table>

RESULTS

• Before: 3,102,900 kWh  
• After: 1,343,300 kWh (57% reduction)  
• System was delivered on schedule by Global Solutions  
• “We had originally hoped for a savings of around $55,000 a year the savings will be closer to $110,000 a year, conservatively”  
• “We have also realized other benefits such as the ability to monitor water usage, monitor energy usage and run times, as well as control system pressure. This information is helping us identify more ways to conserve energy and reduce water usage.”  
• Three more pump system candidates are in the plant
**Large Central Utility Plant**

**Centrifugal Pump Optimizer Solution**

---

**Energy Reduction and OEM Skid Integration of Chilled Water Pumping System**

### CHALLENGE

- Higher energy consumption than required
- Control chilled water pumping system
  - 3 x 250HP centrifugal pumps in parallel
- Ease of troubleshooting and maintenance
- Integrate multiple skid vendor equipment
  - Chillers
  - Boilers
  - Pumping Systems
  - Cogeneration – GTG & HRSG
  - Electrical Controls
  - Emergency Generation

### SOLUTION

- Solution delivery/execution description:
  - Interfaced with Alarms & Events, OEM’s and customer for Integrated Architecture® with FactoryTalk® Alarm & Events for integrated alarming
- Pump Solution Kit
  - Standard code loaded onto predesigned panel
  - Panelview Plus displays system status
  - Dispatch equipment energy efficiently
  - FactoryTalk View – redundant
  - FactoryTalk EnergyMetrix™
  - FactoryTalk ViewPoint
  - ControlLogix® - redundant
  - Remote access

### RESULTS

- Reduced energy consumption
- Integrated alarms and events between skid vendor HMI and Plant HMI
- Remote access reducing onsite labor costs and fast troubleshooting
- One system to view multiple functions reducing maintenance, hardware and software costs
- Minimal annual support costs
Questions?