Benefits of a Cooling Tower VFD Retrofit

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Agenda

- Project Introduction
- Project Development & Justification
- Key Decisions
- Installation Overview
- Control Scheme Modifications
- Results
- Additional Benefit
- Final Thoughts
Project Introduction

- Laramie River Station
- Located in Wheatland, WY
- Two cooling towers for each unit
- Each tower has 12 – 150HP 2 speed fans
- Fans were powered by two speed starters in MCCs.
- Hardwired control scheme from the plant DCS.
- Operators were responsible for determining fan operating speeds.
Project Introduction – One Line Diagram

To 6.9kV SWGR

TOWER A

480V SWGR

MCCs

150 x 6

TOWER B

480V SWGR

MCCs

150 x 6

To 6.9kV SWGR
Project Justification

► Reliability
  • Cable faults become a frequent occurrence
  • Electrical equipment at end of service life

► Maintenance Problems
  • Gearbox Failures
  • Driveshaft Failures

► Efficiency
  • Would any cost savings be realized?
  • Would an improved control scheme offer savings?
Project Justification – Do VFD Cost Savings Exist?

- Information comparing power usage prior to and after a 2 speed starter to VFD retrofit was not available to BMcD and Basin.

- VFD applications have additional considerations:
  - HVAC Equipment
  - Harmonics
  - Existing Motor Compatibility
  - Fan & Gearbox Minimum Speeds

- VFDs were more expensive than the two speed starter solution
Project Justification - Efficiency

- Horsepower is proportional to the cube of speed

\[
\frac{HP_2}{HP_1} = \left(\frac{\text{Speed}_2}{\text{Speed}_1}\right)^3
\]

- Speed and flow are related by the fan curve
Many factors impact the outlet water temperature.

The cooling performance curve for a tower will look different depending on the conditions.

A relationship between outlet water temperature and fan speed, excluding other environmental factors is not attainable.
Horsepower Comparison of Different Motor Configurations

- **HP 2 SPEED**
- **HP VFD**
- **HP ACROSS THE LINE**

Note: This Chart Neglects VFD Efficiency Losses.
VFD efficiency must be examined at different loading conditions.

VFD efficiency will vary from manufacturer to manufacturer.

VFD Efficiency by Fan Speed

<table>
<thead>
<tr>
<th>Fan Speed</th>
<th>58%</th>
<th>62%</th>
<th>73%</th>
<th>79%</th>
<th>84%</th>
<th>90%</th>
<th>93%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 HP</td>
<td>99%</td>
<td>99%</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>97%</td>
<td>97%</td>
</tr>
<tr>
<td>200 HP</td>
<td>97%</td>
<td>97%</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>97%</td>
<td>97%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Source: Siemens (2017)
**Decision Point**

- **Variable Frequency Drives**
  - Mechanic’s made a case that VFD’s would save on maintenance

- **Control Scheme Typology Redesign Required**

- **Additional Considerations**
  - HVAC Equipment
  - Harmonics
  - Existing Motor Compatibility

- **VFDs were more expensive than the two speed starter solution**
  - Approximately 30% More Expensive + Cost of Harmonic Filters
Installation Overview

- Major Equipment In The Project
- Eaton Magnum DS Arc Resistant 480V Load Centers
- Rockwell Allen Bradley Arc Shield Motor Control Centers
  - Powerflex 753 VFD & Passive Filter
- Trane 30 Ton HVAC Units
Installation Overview
Control Scheme

► Emerson Ovation DCS System
  • Existing 2 speed starters were hardwired to the DCS

► Variable Frequency Drives Required:
  • Run command
  • Speed reference
  • Direction Command
  • Feedback – Speed, Direction, Alarms, etc.
  • Logic to determine the speed reference
  • New Graphics

► Implemented datalink control from the DCS – DeviceNet & DCS – Modbus
Control Scheme

► Speed Reference Based On:
  • Circulating Water Temperature
  • Designed as a PID loop with circulating water temperature as the process variable
  • Provided operators with the ability to bias the target setpoint -10 to +20 degrees

► De-Icing sequence utilized the VFD’s in reverse at 50% speed

► Speed limited between 30% and 90%  
  • Based on advice from the VFD manufacturer for a 90%-30% speed limit when using non-VFD rated motors.
  • At low speeds some gearboxes may lack adequate lubrication.
Control Scheme Lessons Learned

- VFDs would trip shortly after start command due to high DC bus voltage
  - Passive filter capacitors boosted voltage too much, **solved by adding a contactor to close in capacitors at >50% speed.**
  - Also, no load current draw of capacitors was ~60A, resulting in large reactive current load
Control Scheme Lessons Learned

DeviceNet Communication Issues

- Communication from DCS to VFDs occasionally would go down for a brief instance
- Loss of feedback would reject controls to manual and flood alarm screen
- Could not correlate to any specific load condition or operational scenario
- Using 125k baud rate, low number of devices per segment (<15), no bus errors detected
- Revised DeviceNet power supply wiring, tried different media converters…no effect
- **Solved by changing DCS scan time from 4/sec to 2/sec**
  - Allowed more time for end devices to receive commands and send responses
- Recommend having DeviceNet meter for troubleshooting
Motor Reversing in Cold Weather

- Commissioning of VFDs took place in summer months, no issues running in reverse
- During cold weather, not able to start VFDs in reverse to de-ice the towers
  - Trip on Input Phase Loss (protects drive capacitors from excessive DC bus ripple)
  - Attempted raising threshold of parameter in VFD, limited success
  - Removed trip based on this parameter, Rockwell had concerns
  - Other plant in ND having similar issues after VFD retrofit, provided parameters to investigate
  - Recommended tuning VFDs for high inertia loads
  - After tuning VFDs, all fans able to start in reverse during cold weather

<table>
<thead>
<tr>
<th>#</th>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>377</td>
<td>Bus Limit Kd</td>
<td>0</td>
</tr>
<tr>
<td>378</td>
<td>Bus Limit ACR Ki</td>
<td>650</td>
</tr>
<tr>
<td>463</td>
<td>Input Ph Level</td>
<td>15000</td>
</tr>
<tr>
<td>621</td>
<td>Slip RPM at FLA</td>
<td>0</td>
</tr>
<tr>
<td>535</td>
<td>Accel Time 1</td>
<td>60</td>
</tr>
<tr>
<td>537</td>
<td>Decel Time 1</td>
<td>180</td>
</tr>
</tbody>
</table>
Results – Maintenance Savings

Primary Cost Drivers:
► Gearbox & Drive System Repairs
► Occasional Expected Motor Replacement

Summary:
► Average Annual Maintenance Expenditure - 2 Speed $289,641
► Average Annual Maintenance Expenditure – VFD $74,134
► Average Annual Savings $215,507 (74%) per Unit
Results – Energy Savings

Unit 1 Cooling Tower KVA Power Consumption 2014 – 2018

Average KVA Before Upgrade: 2180 KVA
Average KVA After Upgrade: 1744 KVA

Upgrade Completed Spring 2015
Data Recorded Every 30 Minutes With Unit At 70% Load Or Greater
Results – Energy Savings

Unit 2 Cooling Tower KVA Power Consumption 2015 - 2017

Average KVA Before Upgrade: 2272 KVA
Average KVA After Upgrade: 1745 KVA

Data Recorded Every 30 Minutes
With Unit At 70% Load Or Greater

Upgrade Completed Spring 2016
Results – Energy Savings

Unit 3 Cooling Tower KVA Power Consumption 2014 - 2018

Average KVA Before Upgrade: 2455 KVA
Average KVA After Upgrade: 1935 KVA

Data Recorded Every 30 Minutes
With Unit At 70% Load Or Greater

Upgrade Completed Spring 2017
Energy Savings

- Unit 1: 434 KVA ≈ 20%
- Unit 2: 527 KVA ≈ 23%
- Unit 3: 520 KVA ≈ 21%

Applying 0.8 Power Factor To The Average KVA above yields approximately 400kW of aux power savings for each unit.

To estimate the monetary value of the energy savings, use approximately 20% of your cooling tower auxiliary power load.
Additional Benefit – Arc Flash Incident Energy Level

- Reduction in incident energy on the line side of the main breakers via the implementation of a new differential relay.

- Before Retrofit: 34 cal/cm²

- After Retrofit: 5.6 cal/cm²
Final Thoughts

- Motor reliability concerns have not materialized in this installation.
- HVAC requirements can be substantial when working with a large number of VFDs.
- We have seen quantifiable energy savings provided by the VFD and control scheme.
- VFD parameters may require tuning to operate successfully in all ambient conditions.
- The DeviceNet & Modbus datalink control scheme via the Emerson Ovation DCS required troubleshooting, but eventually worked as we desired.
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Questions?

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