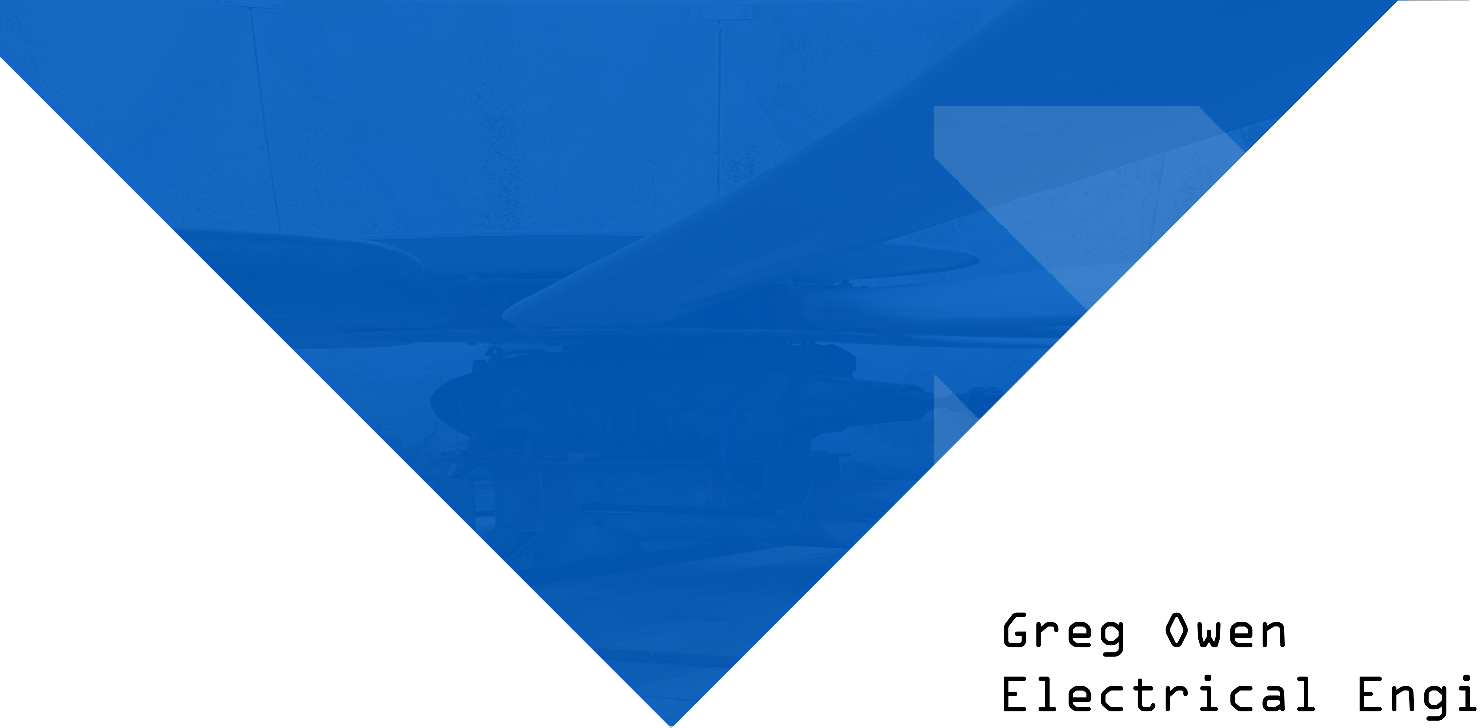


Benefits of a Cooling Tower VFD Retrofit

Greg Owen
Electrical Engineer
BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

Ryan Carlson

Electrical
BURNS McDONNELL

54th Annual MIPSYCON Conference

November 7, 2018

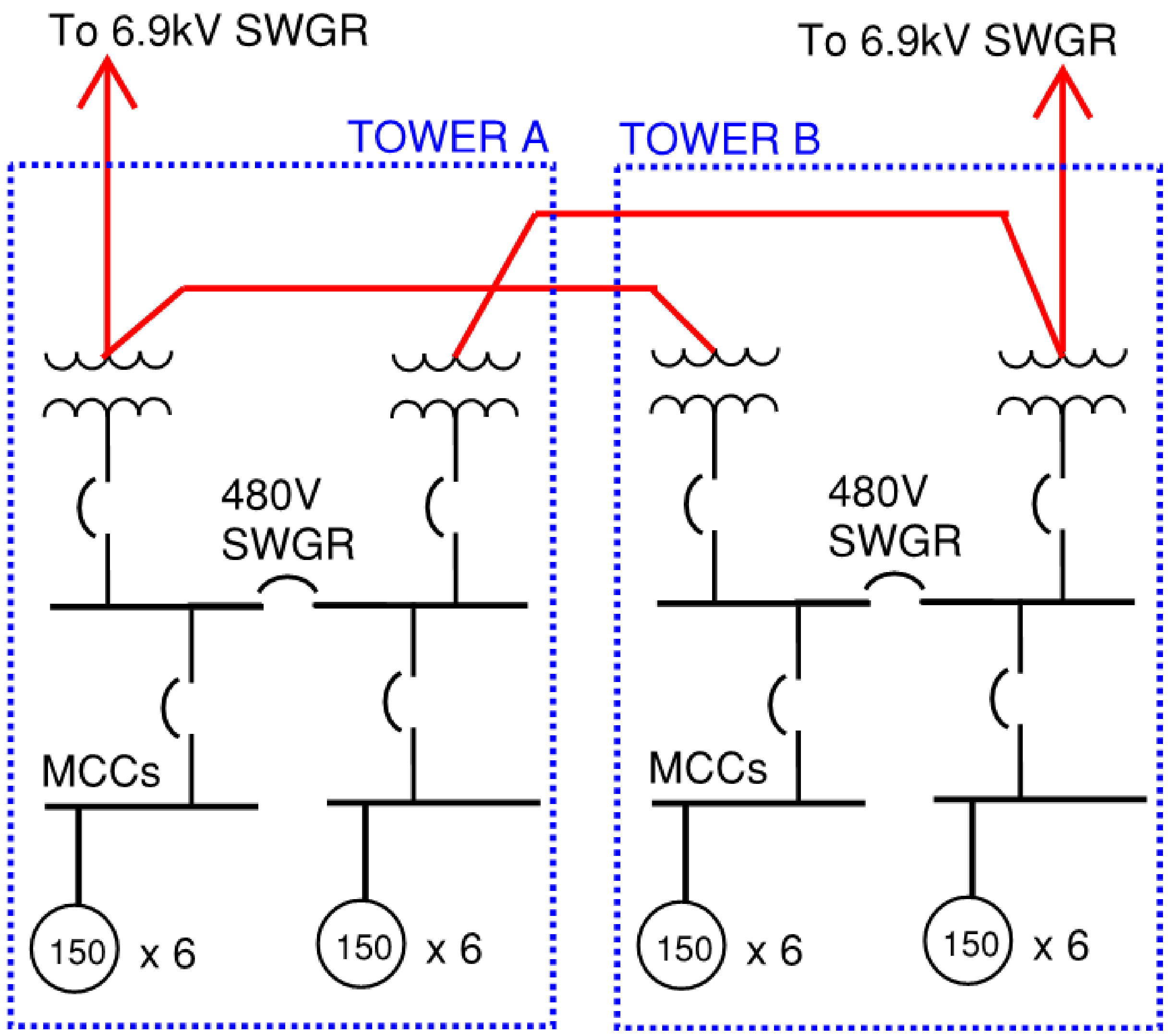
Agenda

- 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
- 3 – 570MW units (1980, 1981, & 1982)
- 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



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

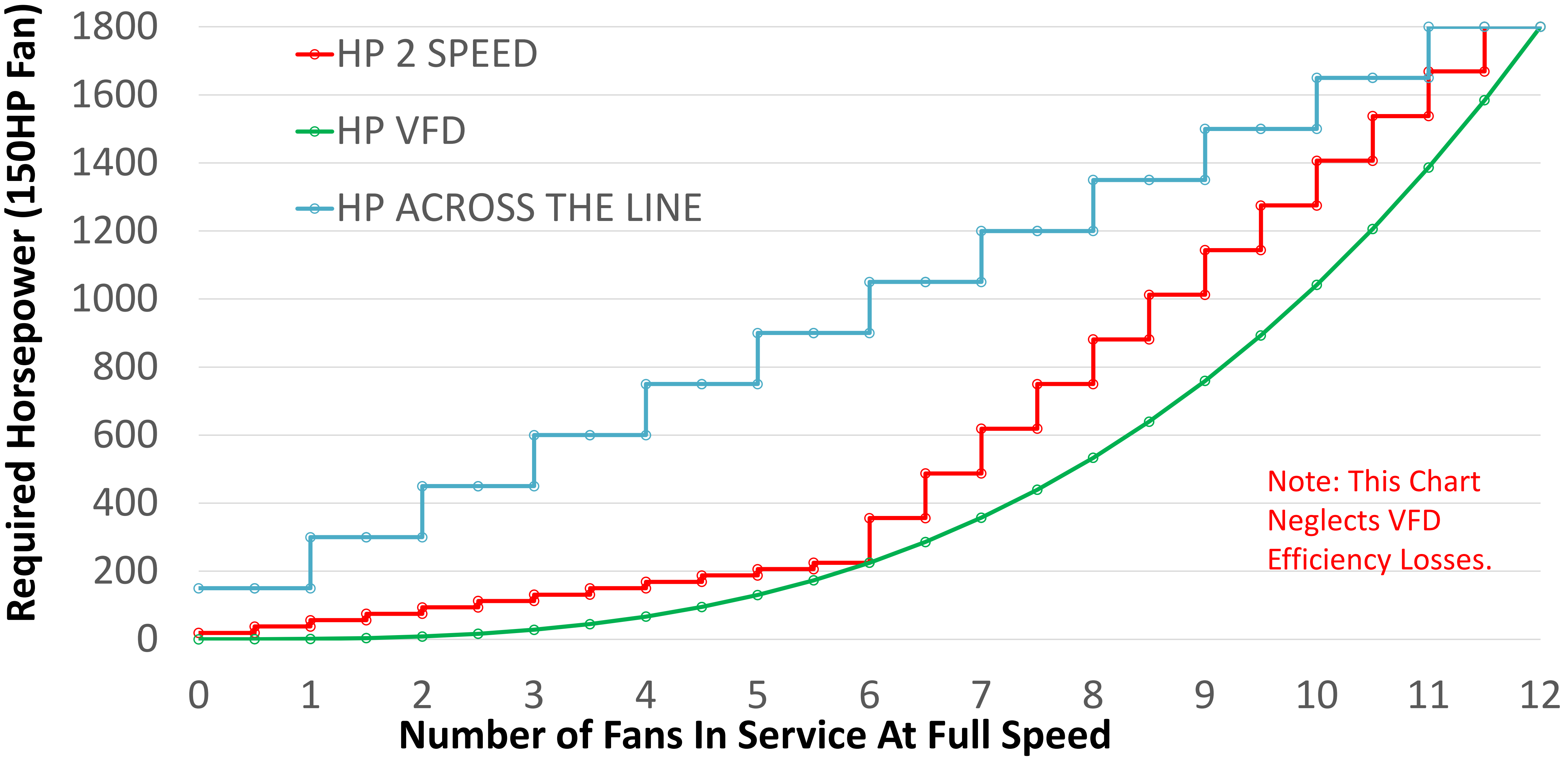
$$\frac{HP_2}{HP_1} = \left(\frac{Speed_2}{Speed_1}\right)^3$$

- Speed and flow are related by the fan curve

Project Justification - Efficiency

- 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



Decision Point

- ► VFD efficiency must be examined at different loading conditions
- ► VFD efficiency will vary from manufacturer to manufacturer

VFD Efficiency by Fan Speed

Fan Speed	58%	62%	73%	79%	84%	90%	93%	100%
60 HP	99%	99%	98%	98%	98%	98%	97%	97%
200 HP	97%	97%	98%	98%	98%	97%	97%	97%

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

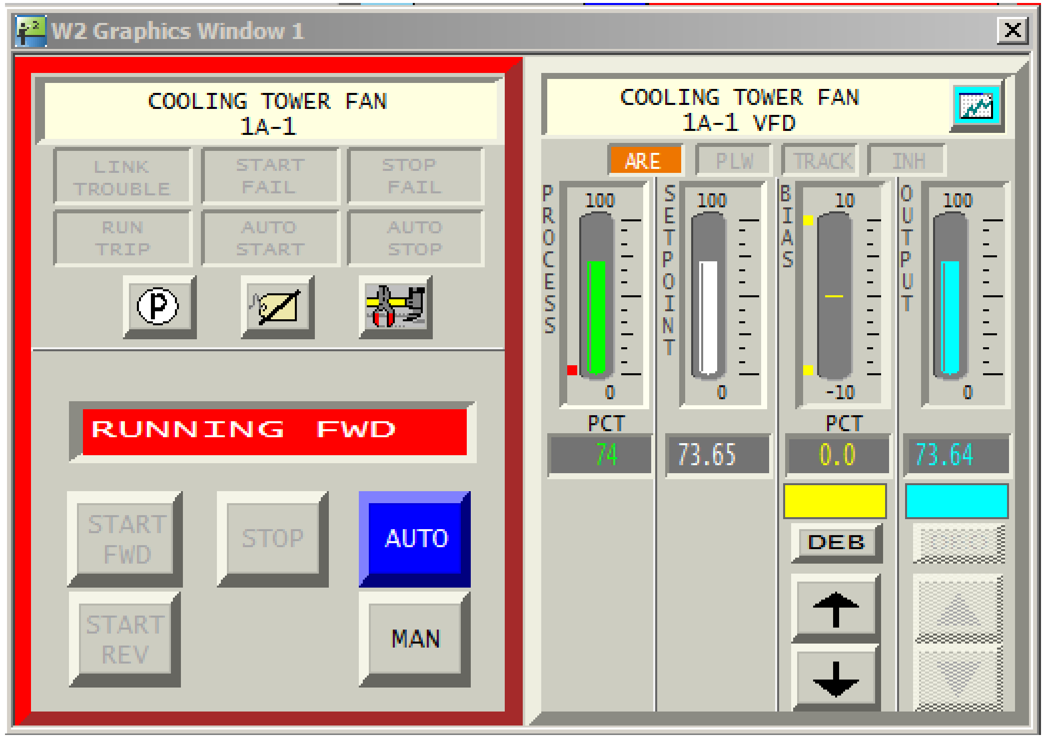
Installation Overview

- ▶ 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

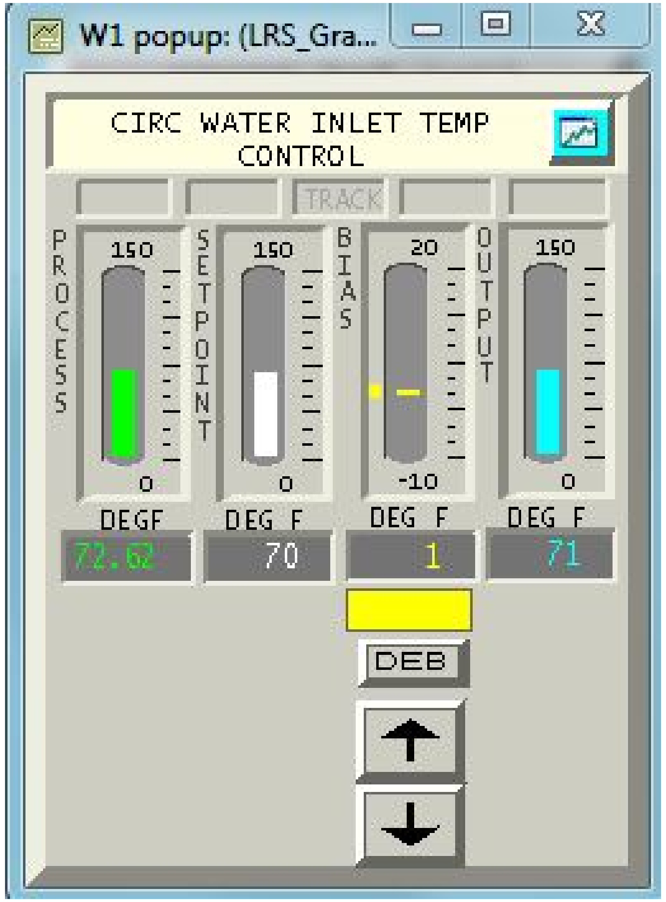
Control Scheme

- 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

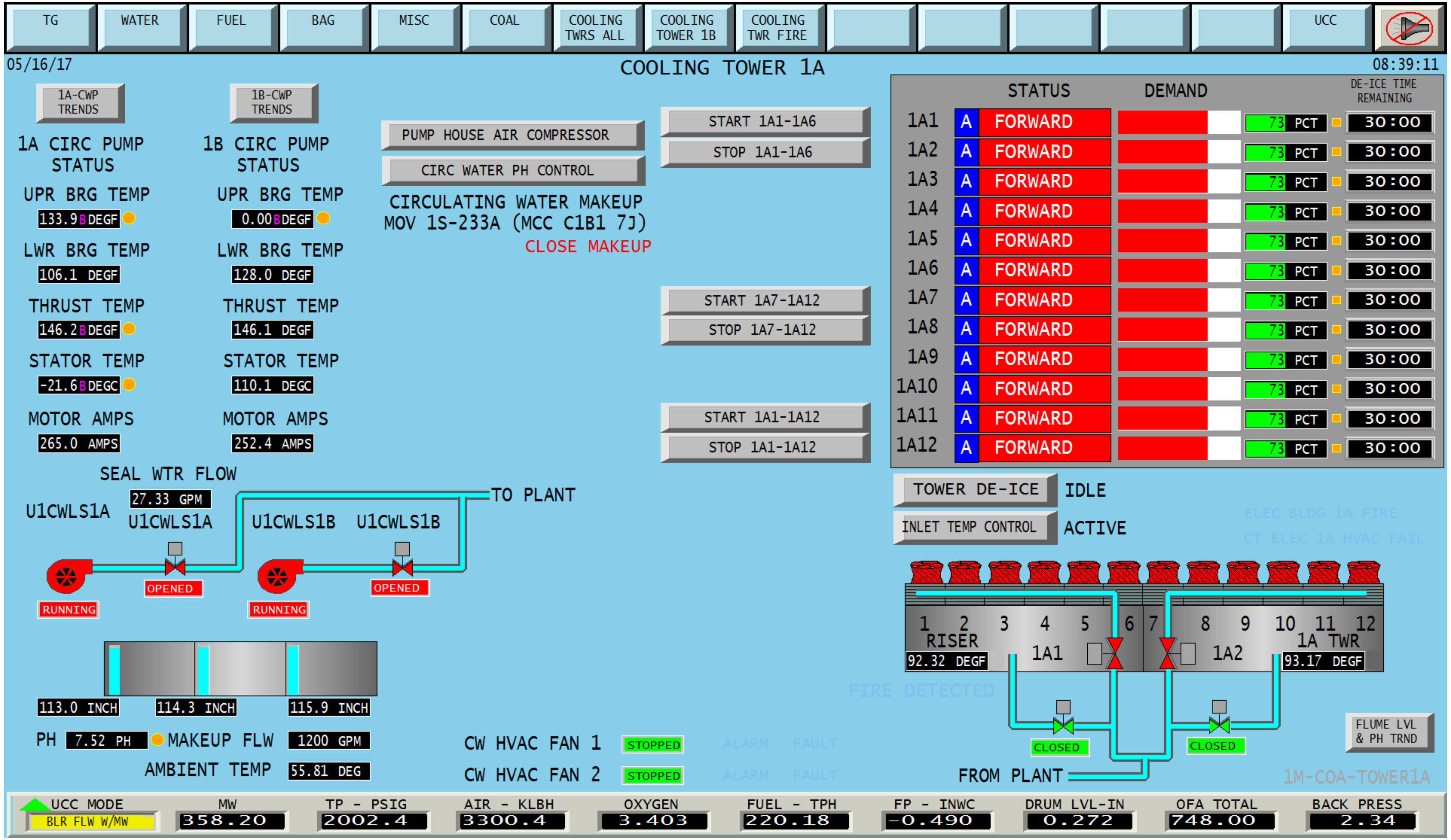


Control Scheme

- ► 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.

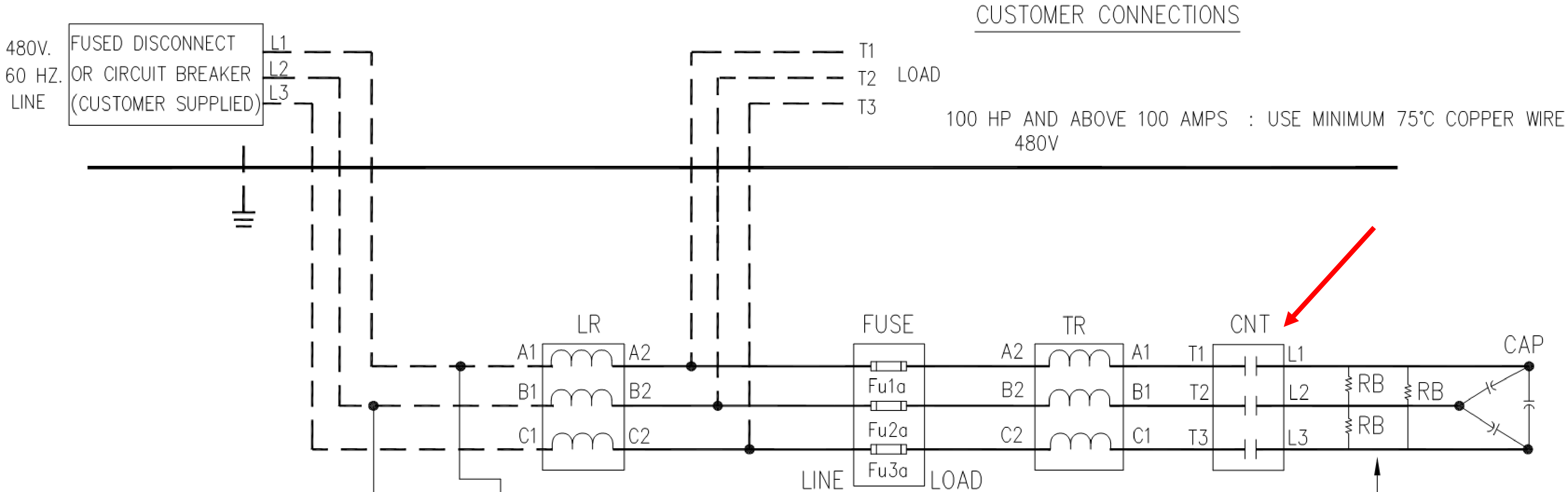


Graphics


TG
WATER
FUEL
BAG
MISC
COAL
COOLING TWRS ALL
COOLING TOWER 1B
COOLING TWR FIRE
UCC
05/16/17
COOLING TOWER 1A
08:39:11
1A-CWP TRENDS
1B-CWP TRENDS
1A CIRC PUMP STATUS
1B CIRC PUMP STATUS
UPR BRG TEMP
133.9 B DEGF
0.00 B DEGF
LWR BRG TEMP
106.1 DEGF
128.0 DEGF
THRUST TEMP
146.2 B DEGF
146.1 DEGF
STATOR TEMP
-21.6 B DEGC
110.1 DEGC
MOTOR AMPS
265.0 AMPS
252.4 AMPS
PUMP HOUSE AIR COMPRESSOR
CIRC WATER PH CONTROL
CIRCULATING WATER MAKEUP
MOV 1S-233A (MCC C1B1 7J)
CLOSE MAKEUP
START 1A1-1A6
STOP 1A1-1A6
START 1A7-1A12
STOP 1A7-1A12
START 1A1-1A12
STOP 1A1-1A12
STATUS
DEMAND
DE-ICE TIME REMAINING
1A1 A FORWARD 73 PCT 30:00
1A2 A FORWARD 73 PCT 30:00
1A3 A FORWARD 73 PCT 30:00
1A4 A FORWARD 73 PCT 30:00
1A5 A FORWARD 73 PCT 30:00
1A6 A FORWARD 73 PCT 30:00
1A7 A FORWARD 73 PCT 30:00
1A8 A FORWARD 73 PCT 30:00
1A9 A FORWARD 73 PCT 30:00
1A10 A FORWARD 73 PCT 30:00
1A11 A FORWARD 73 PCT 30:00
1A12 A FORWARD 73 PCT 30:00
TOWER DE-ICE
IDLE
INLET TEMP CONTROL
ACTIVE
SEAL WTR FLOW
27.33 GPM
U1CWLS1A
U1CWLS1A
U1CWLS1B
U1CWLS1B
TO PLANT
OPENED
OPENED
RUNNING
RUNNING
113.0 INCH
114.3 INCH
115.9 INCH
PH
7.52 PH
MAKEUP FLW
1200 GPM
AMBIENT TEMP
55.81 DEG
CW HVAC FAN 1
STOPPED
CW HVAC FAN 2
STOPPED
1 2 3 4 5 6 7 8 9 10 11 12
RISER
1A1
1A2
1A TWR
92.32 DEGF
93.17 DEGF
CLOSED
CLOSED
FROM PLANT
FLUME LVL & PH TRND
1M-COA-TOWER1A
UCC MODE
BLR FLW W/MW
MW
358.20
TP - PSIG
2002.4
AIR - KLBH
3300.4
OXYGEN
3.403
FUEL - TPH
220.18
FP - INWC
-0.490
DRUM LVL-IN
0.272
OFA TOTAL
748.00
BACK PRESS
2.34

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

Emerson and Rockwell service engineers putting their heads together!

- 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
  - **<u>Solved by changing DCS scan time from 4/sec to 2/sec</u>**
    - 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

#	Parameter	Setting
377	Bus Limit Kd =	0
378	Bus Limit ACR Ki =	650
463	Input Ph Level =	15000
621	Slip RPM at FLA =	0
535	Accel Time 1 =	60
537	Decel Time 1 =	180

Programming Manual

Allen-Bradley

PowerFlex 750-Series AC Drives

Results – Maintenance Savings

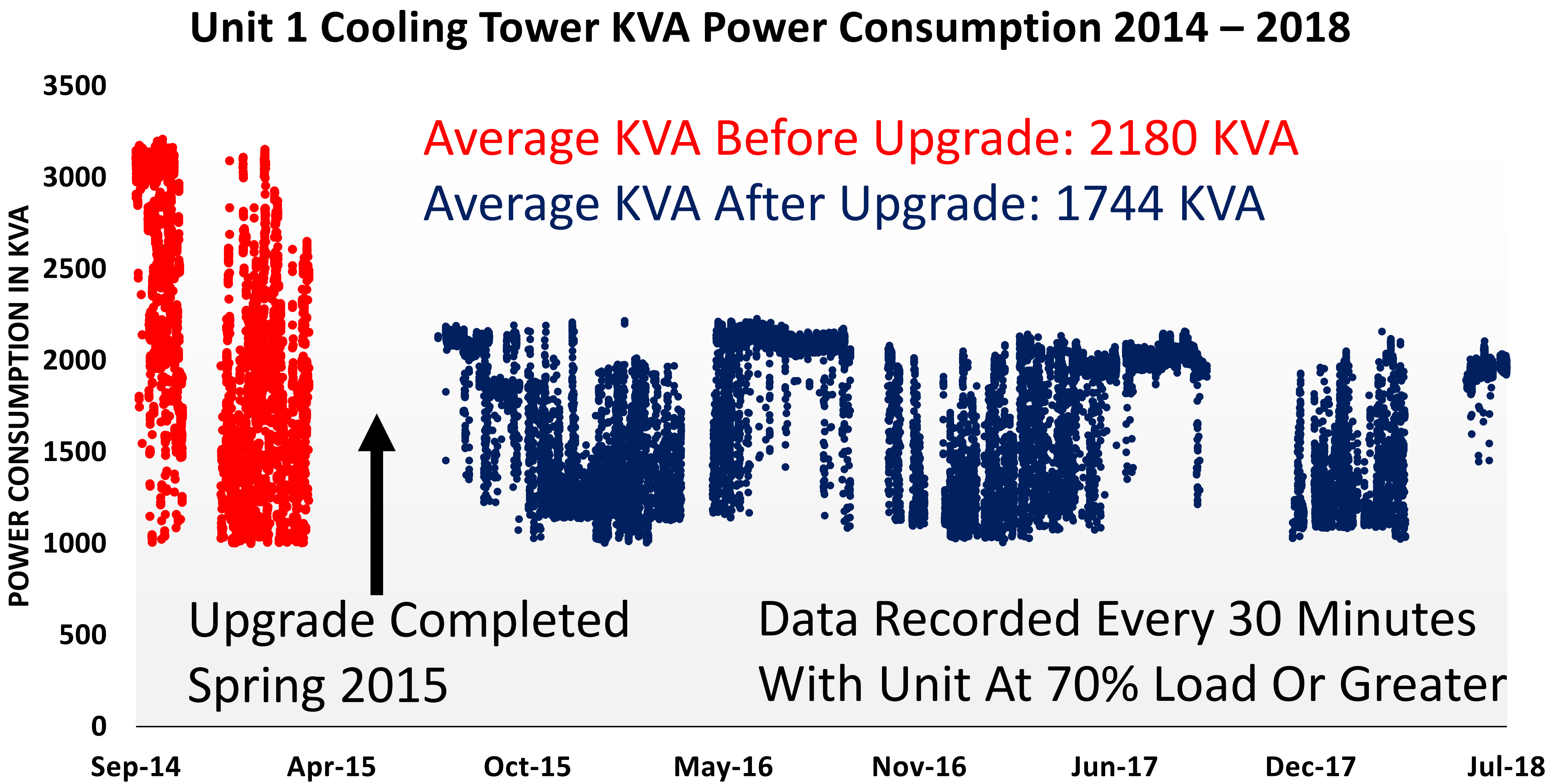
Primary Cost Drivers:

- ► Gearbox & Drive System Repairs
- ► Occasional Expected Motor Replacement

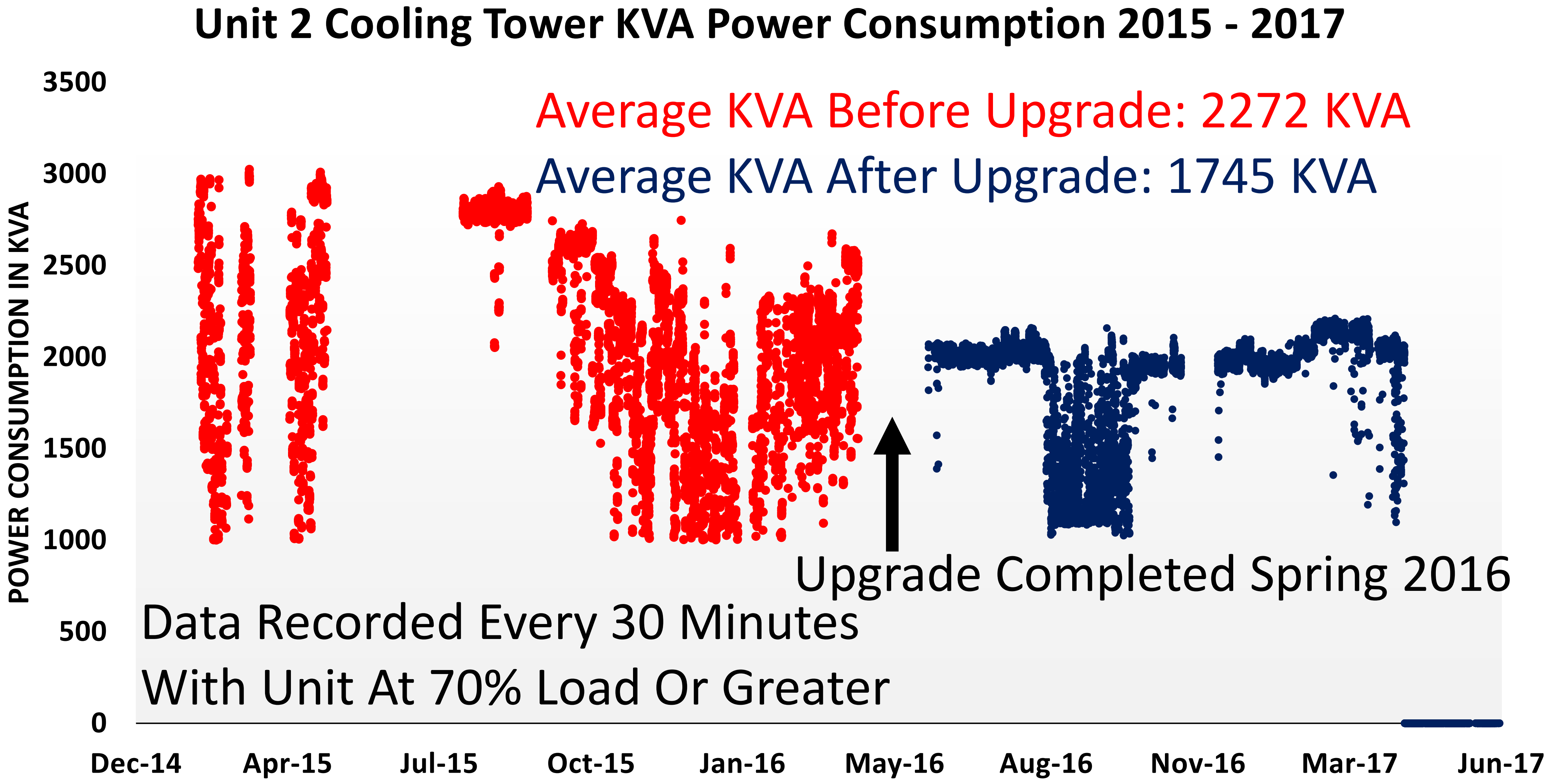
Summary:

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

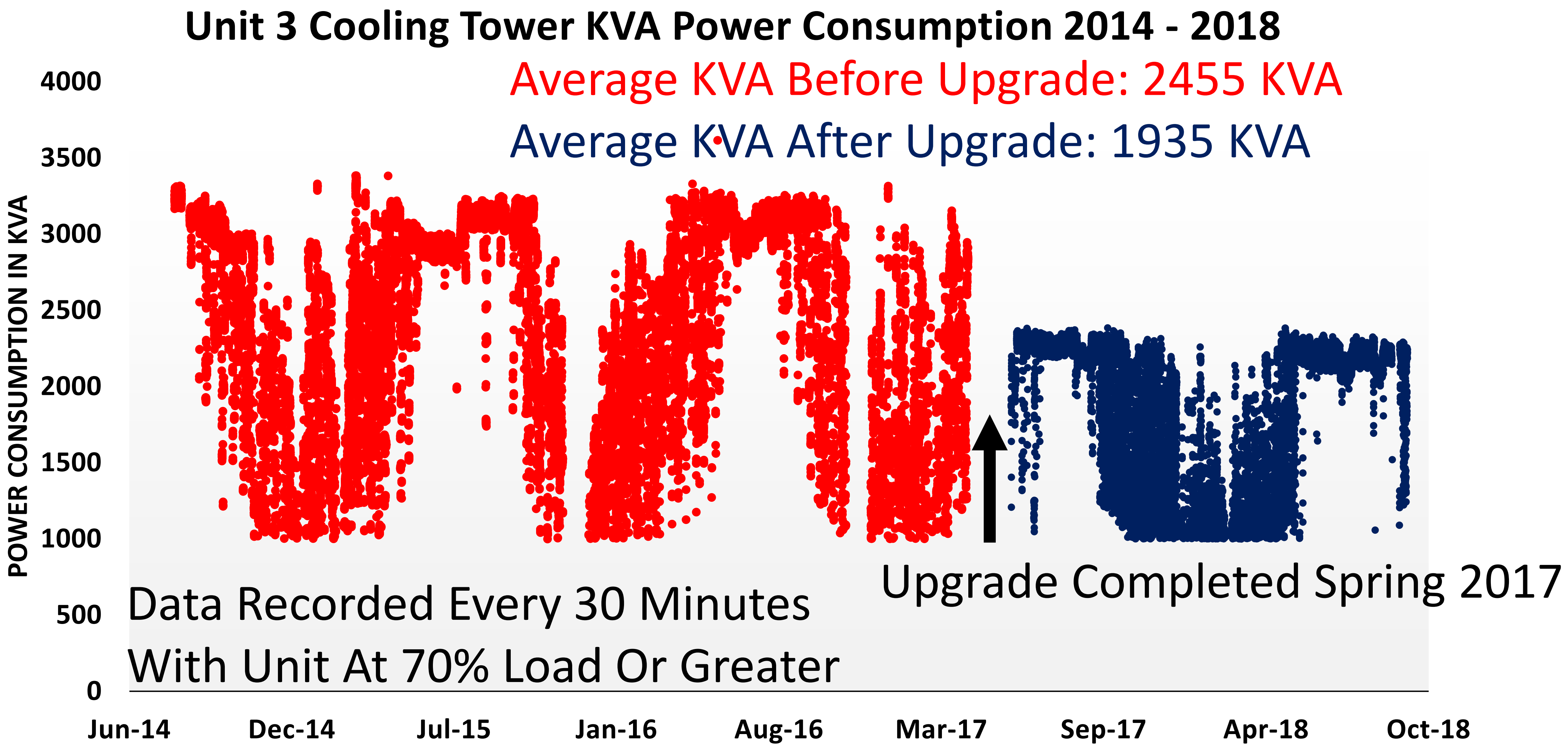
Results – Energy Savings



Results – Energy Savings



Results – Energy Savings

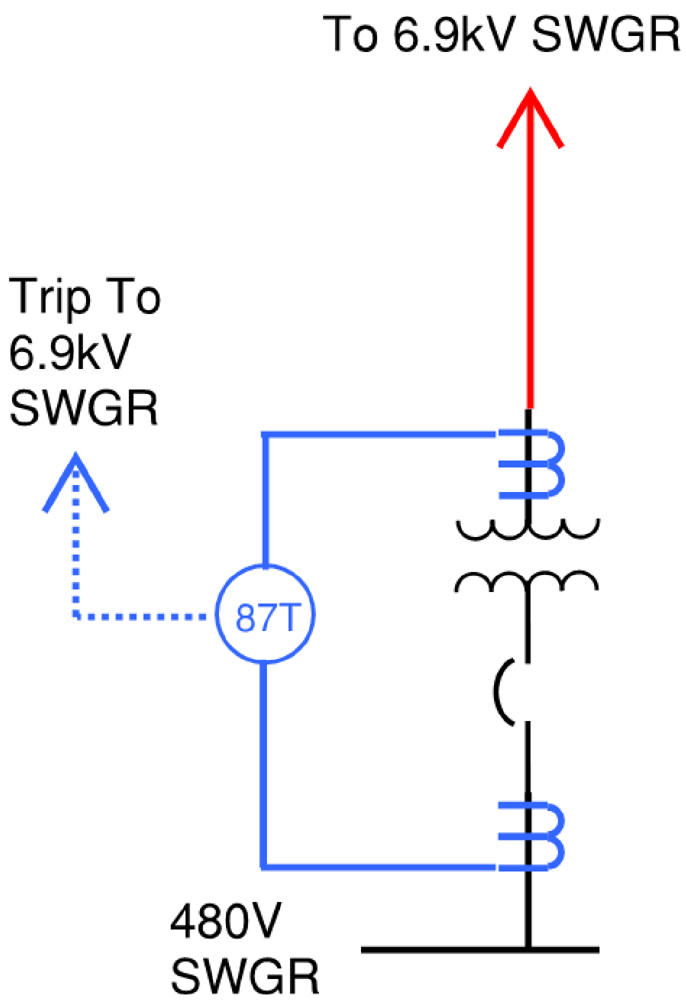


Results – Energy Savings

- 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.

Special Thanks:

- The following companies assisted with the development of this presentation:
  - Rockwell Automation
  - Siemens
  - BTU Company
  - Research Cottrell Cooling

Questions?

Ryan Carlson
Electrical Engineer
Burns & McDonnell, Energy
Phone: 816-822-4358
Email: rccarlson@burnsmcd.com

Greg Owen
Electrical Engineer
Basin Electric Power Cooperative
Phone: 701-557-5138
Email: gowen@bepc.com