COGENERATION PLANT SWITCHGEAR REPLACEMENT IMPROVES SAFETY AND RELIABILITY WHILE MAINTAINING SERVICE TO CRITICAL LOADS

Rachel Mueller, Mayo Clinic
Timothy Coyle, PCT, Inc.

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Franklin Heating Station Statistics

• Established in 1927

• 390 KPH steam, 12,000 tons cooling, 16.1 MW generation

• One of two plants serving the 7.2 million square feet of Clinic campus buildings

• Generation:
  • Condensing turbines TG1 and TG2: 2.5 MW each
  • Backpressure turbine TG3: 6.3 MW
  • Dual-fuel engines DG6 and DG7: 2.4 MW each

• Distribution:
  • Approximately 4 MW to buildings via 13.8 kV and 2400V feeders
  • Emergency/standby power from DG6 and DG7
Justification for Replacement

- Age and Condition
- Inadequate Working Clearance
- Short Circuit Ratings Exceeded
- Protection Shortcomings
  - Many breakers in series
  - Long current differential circuits
  - Complex hard-wired load shedding scheme
# Pre-Project Short Circuit Duties

<table>
<thead>
<tr>
<th>PTW File Identification:</th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
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Available short circuit current exceeds equipment rating
Available short circuit current exceeds 95% of equipment rating
Available short circuit current exceeds 90% of equipment rating
## Upgraded Short Circuit Duties

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- Available short circuit current exceeds equipment rating
- Available short circuit current exceeds 95% of equipment rating
- Available short circuit current exceeds 90% of equipment rating
Design Constraints

• No Additional Space Available on Turbine Floor or in Proximity

• Maintain Crane Access to Basement through Grating in Front of Existing Switchgear

• Maintain Service to Loads and Generation Capacity During Installation and Commissioning

• Narrow Time Window for Taking TG3 Out of Service

• Highly Congested Cable Space Below Existing Switchgear
Selected Option: Three 13.8 kV Buses (Sync Bus)
Protection System Criteria

- Provide Primary and Backup Protection for all Buses and Circuits
- Provide Zoned Primary Protection of Buses and Tie Circuits
- Utilize Micro-Processor Based Relays Consistent with Existing Installed Base
- Provide Metering Data for All Circuits over Ethernet
- Implement Simplified Under-frequency Load Shedding
Protection System Design

- Based on GE UR Platform: F60, F35, G30
- Protection Schemes:
  - Buses: Traditional High Impedance Differential, MIB
  - Tie Circuits: Directional Comparison Permissive Tripping with Backup Time Overcurrent, F60
  - Load Feeders: Time Overcurrent, F60 and F35
  - Generator: C37.102 with Redundant G30s
- IEC 61850 Communications for Tie Circuit Protection
- Redundant Fiber Optic Networks
- Monitoring at Engineering Workstation
Protection Network Diagram
Network Detail at Bus 3 and Bus Z

FRANKLIN HEATING STATION (FHS)

SWITCH 3A  SWITCH 3B  

100M ST mm

SWITCH ZA  SWITCH ZB

WG F60
S F35
G F35
36 F60
H F35
32 T35

Z3 F60
TG3-2 G30
Z5 F60
Z4 F60
TG3-1 G30

Sw 3A & 3B Part Number: GE ML810-125S-P-C1-XX-E1-X

Sw ZA & ZB Part Number: GE ML1200-125S-C1-C8-C8-CH-X
Tie Feeder Protection Logic (F60 - Z5)
Load Shed System Design

- Implemented from RPU ties at Buses 7 and 8 through Bus 5B to Bus Z
- Manual Enable/Disable switch at FHS
- Separate from RPU at Buses 7 and 8 on UF and RCOF
- Arm feeder load shedding at each plant based on separation from RPU and Enable/Disable switch position
- Shed plant chiller load and feeders based on underfrequency setpoints
- IEC 61850 Signals:
  - Enable/Disable status from Bus Z to Bus 7
  - Separation from RPU from Bus 7 to Bus Z
  - Separation from RPU from Bus 5B to Bus Z
Load Shed System Design

Breaker R4 or R5: Trip for $f \leq 59.95$ Hz AND $\frac{df}{dt} > -3.0$ Hz/s

Shed Plant Load at $f \leq 59.90$ Hz

No Shed at Bus 5B

Shed Feeders at Staggered Frequencies

Block 12

161 KV Line To Byron 345

161 KV Line To Silver Lake

BUS 3

BUS Z

BUS 4

Sync

Hilton/ Guggenheim

Mayo

Harwick

BUS 7

BUS 8

TG6

TG1 2.5 M

TG2 2.5 MW

TG3 6.3 MW

BUS 5B

37.5 MVA

37.5 MVA
Bus 7 Load Shed Logic: Shed Plant Loads

Diagram showing the logic for shed plant loads.
Bus Z Load Shed Logic

1. LS EN TIED On (H3a)
2. OPEN AT B7 On (R15)
3. OPEN AT B5B On (R16)
4. BRKR CLOSED On (H5a)
5. UNDERFREQ 1 OP
6. L5 EN ISO On (H5c)
7. BRKR CLOSED On (H5a)
8. 15 CLOSED On (H7a)
9. R1 CLOSED On (H7c)
10. UNDERFREQ 1 OP
11. OR
12. 28 AND
13. LOAD SHED (VO10)
14. 35 OR
15. 34 AND
16. 33
17. 32 OR
18. 30
19. 27 OR
20. 26 AND
DEMOLITION, INSTALLATION AND COMMISSIONING

- Reliability Expectations
- Tasks
- What led to things going smoothly?
Mayo Clinic Campus Utility Expectations

• Zero Electrical or Utility Outages

• 6 Week Turbine Outage

• Plant Staff expected to “Maintain” Plant Operations

• New Gear but Existing Infrastructure

• 3 Phases of Project Required “Temporary” Connections
TASKS

- End-to-End Relay Testing
- Electrical Switching Procedures
- Operation of Electrical System
End-to-End Relay Testing

GOAL: Function test system components simultaneously

• Settings
• Communication
• Fiber Optics
• Network
• Coordination
TEST STATION

Created Test Stations to Simulate End-to-End Installation

Tested Protective Relaying Elements

Tested Load Shed Signals

Verified Functionality and Operation of Gear
At project completion we used On Line Monitoring to verify Remote I/O
Electrical Switching Procedures

• Live-Transfer Switching Done Off Hours (night/weekend)

• Procedures Allowed Safer Practice for Switching Load

• Insured Safety of Personnel - LOTO

• Updated Procedure Led to Zero Switching Outages
Electrical Switching Procedures

FRANKLIN HEATING STATION - ELECTRICAL LOCKOUT FORM

Move Feeder Loads off Bus 6 (Feeder 6G to 5G and 6H to H)

March 19th

CAUTION: WHEN PERFORMING PROCEDURE AND IF EXPECTED RESULTS DO NOT HAPPEN CORRECTLY, STOP PROCEDURE AND RETURN TO NORMAL BY WORKING PROCEDURE BACKWARDS.

<table>
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<th>LOCATION</th>
<th>SWITCH OR BREAKER</th>
<th>OPEN?</th>
<th>LOCKED</th>
<th>TAG#</th>
<th>TAG</th>
<th>REASON</th>
<th>EXPECTED RESULT</th>
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<td>Bu5Bldg</td>
<td>Bu5A</td>
<td>Breaker 5G</td>
<td>CLOSE BREAKER</td>
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<td>1</td>
<td>NOTICE</td>
<td>Live Transfer Fdr 6G to 5G</td>
<td>Amps should balance between 5G and 6G - RPU is All amps should have been</td>
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<td>NOTICE</td>
<td>Load moved to Fdr 5G</td>
<td>Amps should balance between 5G and 6G - RPU is no longer tied</td>
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</tbody>
</table>

1. Load on Feeder 6G AMPS: ________
2. Load on Feeder 5G AMPS: ________ should be zero

*Call RPU to notify that FDRS 5G and 4G will be paralleled and verify the tie is closed

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TIME AND EFFORT

• DRAFT PROCEDURE WRITING
  • 1 PERSON ~4 HOURS

• WALKDOWN
  • 3 PERSON ~1 HOUR

• FINAL PROCEDURE AND REVIEW
  • 1 PERSON ~ 1 HOUR

• PERFORMING SWITCHING PROCEDURE
  • 4 PERSON ~ 1 HOUR before
  • 4 PERSON ~ 1 HOUR after

21 PROCEDURES
= 336 HOURS
DEDICATED TO WRITING AND PERFORMING SAFE SWITCHING
Operation of the Electrical System

- Configuration was Complex During the Installation Process
- Electrical System was Changing Daily and was Difficult to Operate
- Management Utilized Tools to Protect from Operation Error
Simplified One-Lines
What led to things going smoothly?

- **PRIORITIZING**
  - Safety First
  - Reliability

- **PLANT PREPARATION**
  - Utilized other project opportunities to prepare
  - Field verification

- **CULTURE**
  - Communicate openly
  - Team
What Happened?

• We Got Comfortable

• Started with a Schedule Change…. 

• We Didn’t Allow for any Mistakes to Occur – Failed to Plan for Human Error
Questions?