Case Study: Substation Foundation Replacement Utilizing Helical Piles

MIPSYCON 2019
Speaker Introductions

Jordan Guck, P.E.
» Ulteig
  – Engineering Supervisor

» Waterville Project Role
  – Substation Structural Engineer

» Favorite Hobby
  – Hunting/Fishing

Brendan Cohen, PMP
» Xcel Energy
  – Transmission Project Manager

» Waterville Project Role
  – Project Manager

» Favorite Hobby
  – Hockey
Overview

» Project Background
   – Waterville Substation

» Design Considerations

» Construction Phase

» Q&A
Project Background

Brendan Cohen
Project Need

» Distribution
  – Overloaded and old TR2
    • 107% overload
    • Potential customer growth in area
  – Voltage conversion from 4kV to 23.9kV
    • Remove 4kV service
    • Consolidation of three substation service voltages to two (23.9kV and 12.5kV)

» Transmission
  – More than three elements per bus
    • Pre-existing issue prior to transformer project
Project Scope

» Distribution
  – Replace existing 69-4kV transformer with new 69-23.9kV transformer
  – Remove deteriorating 4kV equipment from substation
  – Install new 23.9kV feeder
  – Convert 4kV service to 23.9kV

» Transmission
  – Install new gas circuit breaker in bus tie position between bus #1 and bus #2
  – Install two 69kV MOD switches for bus tie breaker isolation
Scope Alternatives

» Field transfer all 4kV load to TR1 and remove 4kV substation equipment
  – Larger contingency risk for loss of TR1
  – Limited load growth capability

» Field transfer all 4kV load to TR1, remove 4kV substation equipment, and upgrade TR1 to 28MVA
  – Larger eventual contingency risk for loss of TR1
  – Would have required circuit switcher

» Field transfer all 4kV load to TR3 and remove 4kV substation equipment
  – Overloads TR3

» Build new substation
  – High cost (approx $7-8M)
  – Feeder reroutes to accommodate new substation
Outage Constraints

» Distribution
- Service provided by mobile substation during construction work

» Transmission
- Xcel System Operations requested substation bypass
  - Elysian and Morristown Substations would have been radial without bypass
  - Moved all 69kV line protection to 4S185 breaker to facilitate bypass between West Faribault and Wilmarth Substations
  - Relocate existing bus PT’s to line
  - Preferred solution due to three-terminal configuration between Wilmarth, Waterville, and Cleveland Substations
Final Physical Arrangement
Summary of Physical Scope
Structural Design Considerations

» 69kV Box Structure
  - New line tension
  - New equipment load
  - New bay
  - Demo existing bay
    • Impact to Lateral System
  - Cross-bracing removed

» Distribution Box Structure
  - Upgrade to 23.9kV from 4kV
    • Larger Equipment
  - New equipment
Design Challenges

» Original drawings date back to 1949
» As-built conditions differ from drawings
» No existing calculations on record
  – Designed to outdated loading criteria
» Congestion/Space constraints
» Foundations…
Existing Foundations

What’s wrong with these photos?
Geotechnical Considerations

- “The very soft to soft clays and the swamp deposits have very low strength...”

- “Adequate bearing could be achieved by drilled piers between depths of about 20 to 30 feet...”

Deeper deposits of very soft to soft clays and swamp deposits exist at Borings SB-3 and SB-7. Boring SB-3 showed soft to very soft clays to a depth of about 9 feet, and loose silty sands from about 9 to 13½ feet. It is our opinion, however, that these soft clays and sand would not support more heavily loaded structures like the transformer, and likely would have had higher N-values had drilling fluid been used.

Adequate bearing could be achieved by drilled piers between depths of about 20 to 30 feet, or possibly less. We have also considered the use of helical piles to support the transformer; however, it is our opinion that drilled piers would work adequately and would not require mobilization of another contractor.

It is our judgment that the 23kV and 69kV box structures can also be supported by drilled piers. Because of the depths of compressible soils, the piers will have to be drilled deeper than normal to reach soils that would provide adequate bearing capacities.
Red Flags?
Now What?

Decisions, Decisions...
Why Helical Piles?

> **Advantages**

- Install without demo of existing structure
  - Advantageous to construction duration/cost
  - Minimize outage requirements
- Minimal Overhead Clearance requirement
- Penetrate thru weak soil layers to firm bearing
- Straddle existing spread footings
- Steel-Steel Connections in some instances
- Xcel Energy In-House crews able to install without specialty contractor
What is a Helical Pile?

» In General…
- A helical pile is a deep foundation system used to resist compression, tension, and lateral forces.
- Installed to a pre-defined torque using a helical drill rig
- High strength steel flighting and shafts vary in size depending on design needs

» Other Known Alias’
- Helical Pier
- Helical Anchor
- Screw Pile/Pier
- Screw Anchor

» Photo Credit to Viking Helical Anchors, our supplier for this project
Foundation Details
Frost Considerations
Steel-Steel Bolted Connection

69kV PT Stand (Single Column)

7.0" (0.337" WALL) x 7.0 LEAD (10" x 1/2"), HEOG HELICAL PILE (TYP), INSTALL TO PILE MFG. SPECIFICATIONS
SEE VENDOR DRAWINGS NX 28205-1

DETAIL X
HELICAL PILE "F4"
Waterville Foundation
Fun Facts

» 4.50” OD Piles used: 104
  – Average depth to required install torque around 40ft
  – Some piles started to run; torque reductions considered

» 7.00” OD Piles used: 4
  – Used at steel-steel connections

» 7 Different Foundations with Helical Piles
  – Transformer slab
  – Congested areas required some foundations to support 2 columns

» New Breakers & Regulators utilized Slabs-on-Grade
  – With soil correction provisions
Construction Challenges

» Existing substation with energized equipment
» Winter construction
» Congestion/Space constraints
» New technology for Xcel Energy in-house crews
  – Prior to this project, helical pile work was subcontracted out to specialty contractors

» Weather…
  – Fall 2018: Waterville Tornado
    • Pre-Mobilization
  – Jan 2019: MN Polar Vortex
    • During Construction
  – Spring 2019: Waterville Flooding
    • During Construction
Construction Phase

Brendan Cohen
Held 3 Pre-Construction Meetings
   - Each meeting oriented around four readiness categories
   - All meetings included Project Management, Distribution, Substation Engineering, and Construction representatives

Focus on Four Construction Readiness Categories
   - Construction Drawing Packages
   - Material Delivery
   - Outage Sequencing & Coordination
     - Including bypass plan
   - Mobile Substation Setup
» **Lead Time**
- Viking Helical Anchors provided a 3-4-week lead time

» **Cost & Quantity**

### Distribution Equip Foundations (Total Material Cost: $73,000)

<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>Foundation Quantity</th>
<th>Piles (Per Found)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer Slab</td>
<td>1</td>
<td>6 (6)</td>
</tr>
<tr>
<td>23.9kV Bus Support Stand – F3</td>
<td>1</td>
<td>4 (4)</td>
</tr>
<tr>
<td>23.9kV Box Structure – Foundation F2</td>
<td>1</td>
<td>6 (6)</td>
</tr>
<tr>
<td>23.9kV Box Structure – Foundation F3</td>
<td>5</td>
<td>20 (4)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8</strong></td>
<td><strong>36</strong></td>
</tr>
</tbody>
</table>

### Transmission Equip Foundations (Total Material Cost: $160,000)

<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>Foundation Quantity</th>
<th>Piles (Per Found)</th>
</tr>
</thead>
<tbody>
<tr>
<td>69kV 3-Phase PT Stand</td>
<td>2</td>
<td>2 (1)</td>
</tr>
<tr>
<td>69kV 1-Phase PT Stand</td>
<td>2</td>
<td>2 (1)</td>
</tr>
<tr>
<td>69kV Box Structure – Foundation F1</td>
<td>14</td>
<td>56 (4)</td>
</tr>
<tr>
<td>69kV Box Structure – Foundation F2</td>
<td>2</td>
<td>12 (6)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>72</strong></td>
</tr>
</tbody>
</table>
» **Duration**
   - 3 Months

» **Cost**
   - Labor & Equipment: $445,500
     - Avg Per Foundation: $15,910
   - Material (Concrete and Helical Piles): $243,000
     - Avg Per Foundation: $8,680
   - **Total: $688,500**
   - **Per Foundation: $24,590**
Questions?
Thank You!
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