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Workers drive in helical piles to augment a 69-kV tower foundation at Henry substation. Helical piles were the only way to go on this project. The work had to be completed in tight quarters, on a short deadline and while the substation was still energized.

Tight Times, Tight Spaces

An ambitious substation rebuild overcomes outage limitations and space constraints.

By **Jamie Page**, **Gary Wood** *and* **Kevin White**, *Northeast Missouri Electric Power Cooperative*

Sometimes things do not go as planned. Northeast Missouri Electric Power Cooperative (Northeast Power) can attest to that. In 2011, it became clear the coop needed to rebuild most of its Henry substation, but it could only schedule a 30-day outage to do so.

To get the project done within the limited outage time, the coop had to do as much work as possible prior to the outage. One of the biggest challenges was finding a way to upgrade eight 69-kV foundations while the substation was still energized. Dealing with planning changes, downpours, late frosts and a transformer failure made the job all the more difficult.

Scope and Challenges

Northeast Power is a generation and transmission cooperative, serving eight member-distribution cooperatives in northeast Missouri and southeast Iowa. It has 56 employees. The coop's Henry substation is located in a critical growth area where voltage sag is a problem. Two 161-kV lines, from ITC Midwest, LLC, power the substation and its single 56-MVA transformer. Three 69-kV feeders exit the substation, but there are eight 69-kV deadend structures: one feeds a capacitor bank, one is a transformer low-side breaker bay and the others are for future expansion.

The substation was built in the 1980s and the transformer was 1973 vintage. System studies showed if that transformer failed, voltage regulation in the area could be a problem. In the existing system configuration, Northeast Power needed a second transformer at the substation. Plans were made to add another transformer and install heavier 69-kV conductors, an additional static wire and flying taps. Thus, the 69-kV substation structure towers would have to support a greater load and increased over-turning moment. When the transformer was added, the towers would have to be upgraded, as well.

With an idea of what the scope of the work would be, the next step was to schedule an outage. Because the substation is in a critical area, the coop could only get an outage when the load was low — in the spring or fall. Northeast Power decided to perform the work in the spring of 2013 and arranged for an outage with ITC Midwest and the Midcontinent Independent System Operator (MISO). A significant amount of coordination and planning was needed to schedule the outage, so other substation improvements also were planned. ITC Midwest's long-term plans included increasing line tensions, which would increase the load on the 161-kV tower. Therefore, Northeast Power planned to replace it, as well.

Get Ready, Get Set

Northeast Power hired V&S Schuler to design and manufacture the three-bay 161-kV structure and one of the 69-kV towers. CLC Engineering was retained to design the other seven 69-kV towers, which were fabricated by Lehigh Utility Associates Inc.

CLC Engineering designed new single-column steel cantilever towers with one further enhancement. To help speed up the rebuild work, the new towers were designed to handle mechanical load coming from only one side, with no load on the other side. This was recommended so that when workers transferred the lines to the new towers during the scheduled outage, the towers would not be overstressed. The stronger towers also would be able to withstand additional mechanical loads Northeast Power might add in the future.

The existing aluminum lattice towers had a 3-ft by 3-ft (0.9-m by 0.9-m) base plate. The new towers had a smaller 1.5-ft by 1.5 ft (0.5-m by 0.5-m) base plate. However, the existing concrete foundations were not adequate for the new structures and loadings. This put Northeast Power's engineers in a difficult position. Thirty days was not enough time to remove the 69-kV towers, tear out the existing foundations, pour new foundations and set the new towers. An alternative solution was required.

CLC Engineering suggested the foundations could be augmented and helical piles could be used to support the new foundation sections. Helical piles can be drilled into the soil with a drive motor, and they are faster and easier to install than a traditional poured-concrete foundation. This seemed like a good solution. More importantly, it was the only viable solution, given the scope of work and time constraints.

However, Henry substation is not a big, spacious substation. Workers could not get drilling equipment into the south side of the 69-kV foundations because of energized bus work and underground duct work. The only option was to extend the foundations to the east, west and north.

While Northeast Power was designing the augmented foundations, it received news from one of its distribution cooperatives that a new fertilizer plant was being constructed in its territory, and the plant would add 35 MW of system load. The utility decided that system stability made installation of a transformer close to the new load the best solution. This was done and allowed the installation of a second transformer at Henry substation to be deferred. The second transformer at the Henry substation is now scheduled for a 2020 installation.

How to Augment a Foundation

Even without the transformer installation, work at the

A work crew installs helical piles around three sides of an existing foundation.

Henry substation was still necessary; the 69-kV towers had to be replaced and the foundations had to be augmented. This alone would require a significant amount of work. For instance, to remove the aluminum structures, the coop would have to remove several switches, conductor and bus pipe. In addition, Northeast Power planned to replace old control cables, add a 161-kV breaker, add two 161-kV disconnect switches, replace several relay panels and replace wiring in the control building. So, engineering and planning for this work continued.

The coop hired a geotechnical firm to perform soil tests and finalized the designs for the new 69-kV foundations. Fortunately, the Henry substation is sitting on about 20 ft (6 m) of good compacted clay. The coop approached Hubbell Power Systems to find a helical pile solution. Northeast Power provided the soil reports, foundation loading requirements and height constraints. Hubbell Power Systems specified which helical piles to use and the torque requirements.

Work Begins

With plans complete, Northeast Power crews began work in the energized substation in March 2013. This included the relatively easy work in the 161-kV yard. The new 161-kV tower was an A-frame and its foundations could be poured beside the existing foundation, in an unimpeded area.

On the 69-kV side of the yard, the work was more challenging. The existing 6-ft by 6-ft (1.8-m by 1.8-m) concrete foundations were 7-ft (2.1-m) deep. To meet the new load and moment requirements, the foundations had to be expanded to 12 ft by 9 ft (3.7 m by 2.7 m). The main problem, of course, was clearances. The vertical restriction was 15 ft (4.6 m). Hubbell Power Systems specified helical piles with shorter-than-typical lead sections, and Northeast Power used 5-ft (1.5-m) extension rods. Even so, the coop had to be creative when it came to driv-

After the helical piles were cut and capped, workers added the rebar dowels and built the concrete form. This foundation is ready for the modified mix of concrete.

ing equipment.

A digger-derrick truck was brought in instead of a larger piece of equipment. Workers had to remove the Kelly bar from the auger and then attach the torque indicator and installation tool directly to the motor shaft. This helped with the clearance issues and gave workers a couple of feet to spare. Nevertheless, the coop had to de-energize and remove the 69-kV transfer bus to begin the foundation work.

Also, energized 69-kV circuits had to be de-energized on an individual basis to allow crews to complete the helical pile installations one foundation at a time. At that point, Northeast Power was facing time constraints and unfavorable ground conditions. Loads, which were normally loop fed, were placed on radial feeds.

Once the piles were in place, work proceeded faster, but the spring weather caused a few problems. It rained every other day. The foundation holes filled up with water and had to be pumped dry on a daily basis. However, the damp soil seemed to make it easier to install the helical piles.

Horseshoes and Porcupines

Each horseshoe-shaped foundation addition is supported by four helical piles: two along the east side and two along the west side. Workers drove the piles in until 12,000 ft-lb (1600 m-kg) of torque was achieved. Then they cut off the top of each pile, 1 ft (0.3 m) below the future concrete surface and welded-on metal caps.

To transfer the shear forces from the new section to the existing foundation, Northeast Power designed a system of dowels. Workers bored 12 horizontal holes 12 inches (0.3 m) deep into each side of the existing foundations, for a total of 36 per foundation. Crews inserted 2-ft (0.6-m) sections of 7/8-inch (22.2-mm) rebar in each hole to tie the whole thing together. Workers noted that, from a top view, "The foundation looked like a big porcupine."

The only minor problem encountered during the installation of the 69-kV foundations was solved with a hammer. Before driving in the piles, workers made up steel cap plates, with precut holes, to slip over the top of the rod. But the top sections of some of the pile extension rods got a bit out of shape after being torqued into place by the digger-derrick auger motor. The malformation of the extension rods was not significant and workers hammered the cap plates on successfully.

The concrete mixture was adjusted to speed up the curing process and ambient temperature was watched carefully. March is typically cool in Iowa and the temperature fell below freezing a few times. When this happened, Northeast Power used insulated blankets over the freshly poured foundations.

By the time the Henry substation was de-energized, on April 29, 2013, 95% of the foundation work was completed, most of the conduit was installed and some of the grounding was done, as well. It is worth noting that, while crews were hard at work in the substation, line crews were systematically inspecting and preparing the lines, so they would be in perfect condition during the scheduled outage. Crews trimmed back trees, and inspected poles and hardware. In one case, a danger pole was guyed before the outage (it has since been replaced).

Then the Transformer Failed

A month before the scheduled outage, the single 56-MVA transformer at the Henry substation tripped off-line and blew gas out of the load-tap changer (LTC) compartment. Workers ran a Doble test and dissolved gas analysis on the unit. It did not look good. Northeast Power initially thought only the LTC had faulted, but, through testing and evaluation, determined the unit

This smooth finished foundation covers all the work involved in the installation of helical piles that were used to extend the foundation from its original dimensions.

ead. Now, in addition to the scheduled work, Northeast r also had to replace the transformer. The unit was sal- l and a spare was installed during the scheduled outage. added to the workload significantly.

ne other unplanned job was completed during the first ays of the outage: crews temporarily connected the sta- 28-MVAR capacitor bank to the 69-kV system with an gency tap. This last-minute decision was made to provide tility a comfort factor — in case there were any system ge problems — while the substation was out of service.

e Result

nis was one of the most complex projects Northeast r has tackled. All of the work and engineering was done use, with the exception of the steel design. Getting ev- ing done required the support and assistance of every tment and person in the cooperative. The substation was rgized on May 29, 2013. Everything was completed on ule. TDW

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Companies mentioned:

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Hubbell Power Systems
hubbellpowersystems.com
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