The years following World War II were nation building years in Australia. Soldiers returned from the European and Asian theatres of war sparking a major infrastructure construction boom. Dams and highways were built to keep up with the growth of towns and cities, which were bursting at the seams, not just from the returning soldiers settling down with their families but also from the many waves of refugees from war torn areas around the globe.

The demand for electricity generation and distribution required for the growing population sparked the expansion of the national power grid with new high-voltage transmission towers appearing across the landscape. However, with an original design life of 50 years, those transmission lines constructed in the 1950s are nearing, or are at the end of, their anticipated service life.

In recent years, the Australian power distribution network has changed from a period of high construction activity in greenfield high-voltage lines to a period that is now focused on reducing cost and maintaining existing assets. Replacing aboveground structural members and electrical components is relatively simple even under live conditions. However, the replacement or repair of tower foundations, many of which are in remote locations, has been a problem that has caused difficulties for power utilities trying to operate on a budget while also avoiding costly and unpopular power outages.

With thousands of miles of aging transmission lines needing life extension work, Piling & Civil Australia (PCA) has developed a patented system of upgrading the foundations with micropiles while under live-line conditions without requiring costly outages. The system is seen as revolutionary by power utilities, allowing the utilities to extend the life of their existing assets until demand increases to warrant the construction of a new line. PCA has been working on a potential solution with Powerlink Queensland for the past 5 years to develop a quick and cost-effective foundation replacement system that can extend the life of its existing asset base anywhere from an additional 5 years to 50 years.

With design support from Quanta Subsurface, USA, PCA recently completed the foundation replacement of 26 lattice tower foundations in the Townsville region of North Queensland. Using a steel bracket (patent pending) to connect hollow bar micropiles to the lattice towers, the installation techniques that were developed enabled the micropiles to be installed within a tolerance of less than about 3/8 in (10 mm) through the existing steel grillage foundation while maintaining live line conditions. The project was an Australian first and a trial by Powerlink for wider use within its network, and it was delivered on time and within budget at one tenth of the cost of traditional methods.
The Solution
Components of the system include two or more hollow bar micropiles installed parallel to the tower leg, which carries tension and compression forces from the tower. Any shear forces are handled by the installation of steel casing in the upper 10 to 13 ft (3 to 4 m) above the bond zone and extending a short distance above ground to the underside of a steel plate. The hollow bars extend through predrilled holes in the steel plate, which are then bolted to the tower leg as close as practicable to the existing connection between the tower and its foundation (known as the "K Point"). The components are galvanized and are designed such that the existing foundations are considered redundant with the micropile foundation, thereby providing up to 50 years of additional design life. The system can be utilized equally well with lattice towers with steel “grillage” or concrete bored shaft foundations. Work is also underway on a solution that can upgrade pole foundations.

Construction Challenges
Safety and Environment: Working on electrical transmission towers carrying live high-voltage lines that were constructed to the standards available in the first half of the 20th century has many challenges. Worker safety controls almost every aspect of the construction, which is then followed closely by access constraints and the remote nature of many tower locations. Specialized equipment and procedures are required to work safely within the “Safe Approach Distance” of live conductors. Workers are required to attend extensive training and site inductions prior to the start of construction, with daily site risk assessments and weekly safety “toolbox” meetings held on each site.

When originally constructed, the towers were located in vacant easements with limited constraints on access and egress. Fifty or more years later, many of these easements are no longer vacant land, and towers are now located in residential backyards and environmentally sensitive farmland. National Parks have also been created around many tower locations, which have had an impact on machinery access and construction operations within the parks.
Installation of hollow bar micropiles

To limit the impact of construction activities, significant effort was undertaken by both PCA and Powerlink Queensland to consult with stakeholders and develop site-specific environmental plans for each individual tower location. All vehicles were washed and cleaned upon arrival to the project to avoid transferring weeds to the region, and each site was assessed for potential runoff and waste handling. Environmental and safety audits were carried out during construction to ensure the safety and environmental plans were being implemented and effective in resulting in zero safety or environmental breaches during the course of the project.

Installation: Installation tolerances were very tight on this project, and were the tightest for any project undertaken by PCA to date. The prefabricated steel plates required a construction tolerance of ±5/16 in (7.5 mm) in plan and less than 0.5 degrees in angle for the 1-1/2 in (40 mm) hollow bar micropiles. These tolerances would be difficult enough on most projects; however, as an additional challenge, the hollow bar micropiles were installed within about 12 in (300 mm) of the tower leg through a steel grillage foundation consisting of a buried steel slatted base and four metal supports rising up from the ground connecting at the K Point.

Information on the exact type and depth of buried grillage foundation was not available; therefore, PCA had to rely on previous experience in locating a “sweet spot” that was discovered during the research and development phase of the project using three-dimensional modelling of various grillage types. Installing the hollow bar micropiles required near surgical precision to avoid striking the existing metal grillage foundation while ensuring the micropiles were in the correct position for the installation of the steel plates that connected the system to the tower leg.

To solve the problem of tight installation tolerances, bespoke jigs were made for both the casing installation and the drilling of the hollow bar micropiles. The jigs were attached to the tower legs and were used to guide the casing and hollow bar micropiles into position within a tolerance of less than 3/16 in (5 mm) for the position location. This resulted in the successful installation of all 104 steel plates without the need for any refabrication.

In addition to the tight tolerances, no geotechnical information was available for the tower locations, which made the design of the bond length of the micropiles impossible prior to the start of drilling. Micropiles rely on the skin friction developed between the grout body and the soil (i.e., grout-to-ground bond), which is usually determined from geotechnical tests prior to installation. To enable the project to advance without geotechnical testing, the design and installation of the micropiles proceeded using conservative skin friction values assigned to the soils based on the feedback and observations during drilling and installation operations. A sacrificial tension testing of installed hollow bar micropile...
Installation of hollow bar micropiles

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In addition to the tight tolerances, no geotechnical information was available for the tower locations, which made the design of the was a success in terms of its technical accomplishments with the accuracy of micropile installation and the determination of the in-situ bond length, the project has delivered a major benefit to the community at large. Power utility companies are able to maintain the exposed sections of their distribution system quite easily even under live-line conditions. However, until now, there has been no simple way of maintaining the structural integrity of the buried foundation elements under the live-line conditions. In the past, maintaining the buried foundations resulted in costly and unpopular electrical outages or in the construction of replacement transmission lines. These costs are a major factor in the cost of the power transmission industry. The ability to extend the life of transmission towers without affecting the power supply and without the incurring onerous costs of constructing new power lines enable power utility companies to completely change the financial modelling of the power distribution networks. To extend the life of existing transmission assets at less than one-tenth the cost of replacement will substantially reduce the cost of delivering energy to consumers. In addition to lowering overall future energy transmission costs, power utilities are currently seeking ways to increase the revenue streams from their existing assets.

Overall Community Benefit: Although the Townsville project was a success in terms of its technical accomplishments with the accuracy of micropile installation and the determination of the in-situ bond length, the project has delivered a major benefit to the community at large. Power utility companies are able to maintain the exposed sections of their distribution system quite easily even under live-line conditions. However, until now, there has been no simple way of maintaining the structural integrity of the buried foundation elements under the live-line conditions. In the past, maintaining the buried foundations resulted in costly and unpopular electrical outages or in the construction of replacement transmission lines. These costs are a major factor in the cost of the power transmission industry. The ability to extend the life of transmission towers without affecting the power supply and without the incurring onerous costs of constructing new power lines enable power utility companies to completely change the financial modelling of the power distribution networks. To extend the life of existing transmission assets at less than one-tenth the cost of replacement will substantially reduce the cost of delivering energy to consumers. In addition to lowering overall future energy transmission costs, power utilities are currently seeking ways to increase the revenue streams from their existing assets.

Tight workspace above electrical substation

Hollow bar micropiles installed at existing transmission tower leg
test pile was installed at each tower site, the information was logged for each lineal meter of drilling, and the test pile was statically load tested to calibrate the drill observations to ensure the production micropiles had sufficient capacity. The ability to install micropiles to a high degree of accuracy without the need for geotechnical testing proved invaluable during the project as the final list of tower locations was not finalized prior to project commencement.

Summary

The technological solution developed and used at the Townsville project allows power utility companies to extend the life of existing assets and to increase the value of existing assets through the addition of data and other services without the need to replace their existing network hardware. The technology also enables the assessment of existing tower foundations, which results in selective maintenance of the tower foundations over several years instead of the need for large amounts of capital, which would be needed for full line replacement. The Townsville project was completed two weeks ahead of schedule at 25% of the cost of traditional concrete foundations and with a spotless safety record.

PCA is currently working with another power utility company on a limited access project to upgrade the foundations on several 90-year-old lattice towers in a mountainous region in New South Wales, Australia. The purpose of the upgrade is to enable additional fiber optic data cables to be installed on the existing tower network, which will increase the value of the existing assets and provide wider community access to high-speed internet across the state. The Townsville and New South Wales projects are the beginning of an exciting new use for micropiles in the power and data transmission industries.

Allan Herse is a founding director and shareholder of Piling & Civil Australia (PCA), where he oversees the technical aspects of its day-to-day operations. He has a bachelor of engineering from the Queensland University of Technology and a graduate diploma in business administration from the University of Queensland in Brisbane. Herse is a chartered professional engineer and registered professional engineer in Queensland.