BURNS & McDONNELL

Study Committee B2

Overhead Lines

11141_2022

CASE STUDY: MEASURING THE SIZE OF ELECTRICAL CONDUCTORS USING LIDAR SCANNING

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Motivation

Measuring the size of conductors in energized transmission or distribution lines can be a dangerous, time-consuming and costly process. However, as technology continues to advance, it is only a matter of time before these conductors can be measured in a safer, faster and cheaper way without sacrificing accuracy. With the new capabilities available in lidar high-density scanning, that time may be now.

Objects of investigation

Terrestrial lidar scanners measure the point-to-point distance between the scanner and a surface millions of times. High-density scans can boost accuracy by increasing the number of data points. However, high-density scans are used infrequently because of the length of time it takes to complete one. The higher the density, the longer it takes to capture data. Fortunately, conductor measurements only require high-density scans of a small section of interest, which slashes this time requirement.

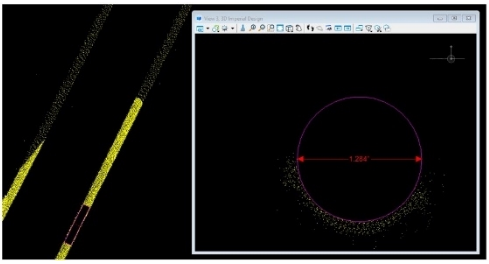

Figure 1: High- vs. low-density scanning

We wished to learn if lidar high-density scanning could provide a safer, faster and cheaper alternative to mechanical calipers. Best known for its use in land surveying, lidar technology is also suitable for other applications that require scientific measurement. However, not all metrology scanners — particularly those that are short-range and intended for indoor use with a physical probe — are well-suited to a substation environment.

The lidar scanners more suitable for this task include a high-density mode. While even a high-density scan cannot distinguish between two conductors with 1/100 of an inch (0.254 mm) difference in diameter, it can (within certain parameters) detect differences of 0.25 inches (6.35 mm) or less. This is believed to be sufficient to distinguish the handful of conductors used by most utilities, minimizing the risk of misidentification.

Scan Points	AB	CD	EF	GH	IJ	KL	ABCD	CDEF	ABEF	GHIJ	IJKL	GHKL	ABCDEF	GHIJKL
Scans	504-507	508-511	512-515	516-519	520-523	524-527	504-511	508-515	504-507, 512-515	516-523	520-527	516-519, 524-527	504-515	516-527
M1 1.453"	-	1.7486	-	-	-	-	1.5105	-	1.4415	1.5159	1.2056	1.7666	1.3588	1.9526
M2 1.382"	-	1.5339	-	-	-	-	1.3572	-	1.3559	-	1.5208	1.8503	1.3497	1.994

Table 1: Calculated measurement of conductor sizes from scans

Method/Approach

We initially sought to collect measurements from completed 3D models composed of multiple scans that had been stitched together. However, we abandoned this approach after finding that the stitching process — which finds the line of best fit and "smoothes out the edges" — complicated the measurement of individual conductor diameters.

Instead, we began by using lidar to conduct an in-field measurement of a conductor for a client, after which we conducted a series of trial-and-error measurements in a simulated environment. Our first task was to assess the feasibility of employing high-density lidar scanning to measure conductor diameter. The next challenge was to determine the parameters for completing the process efficiently and accurately and to develop best-practice recommendations.

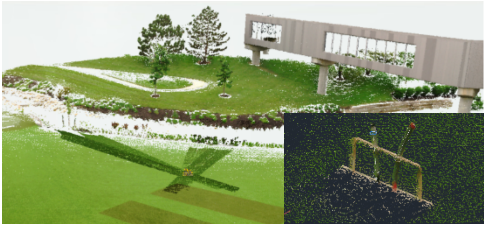

Figure 2 & 3: Manual registration of scan points ABCD (See Table 1) during open field testing and Bent pipe tool measuring diameter of conductor from scan points ABCD (See Table 1)

The original field measurement was performed by combining typical lidar scanning methods with middle-of-the-road resolution. Using a high-density lidar scanner, we completed several high-density scans of the conductor and used FARO SCENE software to register the scans before measuring the conductor's diameter using the Certainty 3D TopoDOT tool within MicroStation software. The project was a success, with the results confirming that the conductor's diameter was, in fact, closer to that of a 1590 AAC conductor. Additionally, we had confidence in the results because we used the same methods on a known conductor within the substation and achieved a similar level of accuracy.

Conclusion

Scans focused on conductors can be an effective way to measure conductor diameter, able to differentiate between and identify different types of conductors.

Measurements taken from 50 feet (15 meters) away required two scans to achieve the density needed to obtain the necessary data, making it the preferred option. Those taken from 80 feet (24 meters) required four scans to produce the necessary density. In comparison, scans taken from 110 feet (33 meters) did not have the density needed to complete the analysis, even with six high-density scans.

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Perform in-field conductor measurement using lidar and register data together.

The field measurement demonstrated that high-density lidar scans could be employed to measure conductor diameter. The next challenge was to determine how to complete the process most efficiently and accurately.

Past attempts had shown that neither 3D models created from lidar nor normal-resolution lidar scans are conducive to conductor measurement. These experiences suggested a need for high-density scanning — a process that normally takes multiple hours to complete.

We subsequently learned from FARO that we could save considerable time by conducting a typical 360° scan and then outlining only a small portion for a high-density scan, a process that could be reduce the task's duration from hours to minutes. This finding led us to change our methodology, relying on high-resolution scans of conductors only.

We initially planned to obtain all essential measurement data from a single scan to limit potential hardware errors. However, measuring a conductor from a single scan is almost impossible with current technology because the outer edges of the conductor do not return data points to the scanner and thus are lost in the scan data collected. We later tested combinations of two, four and six scans taken from different angles of the conductor through a trial-and-error process. This approach enabled us to collect sufficient data while learning if and how we might minimize any "noise" around scan edges and errors created when scans were subsequently stitched together.

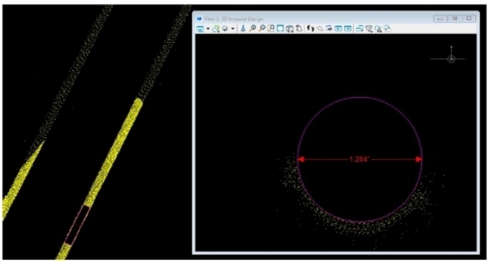

Figure 1: High- vs. low-density scanning

Figure 2: Manual registration of scan points ABCD (See Table 1) during open field testing

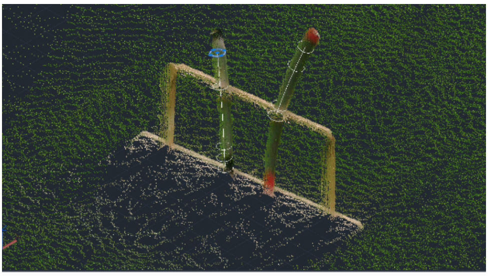

Figure 3: Bent pipe tool measuring diameter of conductor from scan points ABCD (See Table 1)

After FARO reviewed our plans and performed some scans of its own, the manufacturer offered suggestions for minimizing errors and optimizing the process. Several addressed ways to improve the registration process when combining scans. FARO recommendations included:

- Avoid scanning directly below a conductor in the field. FARO's internal testing found scan results are slightly less accurate in the area directly above the scanner. Accuracy improves when scans are conducted on either side of the conductor being measured.
- Limit high-density scans to the immediate vicinity around the conductor to save scanning time. The default of our lidar scanner was a 10°-by-10° box, which we adjusted to a 4°-by-4° box to save scanning time.

We sought to measure two conductors of different diameters from various distances and angles using lidar high-density scans in a simulated environment with our scanning methodology in place. Data from each scan was recorded and then evaluated to assess the accuracy and determine optimal distances and angles for real-world conductor measurement.

The measurements were completed under the following conditions:

Two different-sized conductors (1272 ACSR and 1590 AAC) were placed in a wooden frame in an open field. A centerline was identified, with points indicated at the 50-, 80- and 110-foot (15-, 24- and 33-meter) marks from the conductors. Perpendicular to the centerline, scanning points were identified 10, 20 and 30 feet (3, 6 and 9 meters) from the 50-foot (15-meter) mark; 20, 30 and 40 feet (6, 9 and 12 meters) from the 80-foot (24-meter) mark; and 20, 40 and 60 feet (6, 12 and 18 meters) from the 110-foot (33-meter) mark. (See Figure 4.)

High-density scans were taken of each conductor from two, four or six scan points. (See Table 1.)

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continued

Complete conductor measurements in a simulated environment.

Once the scans were registered, the FARO AsBuilt "fit bent pipe" tool in Autodesk AutoCAD Plant 3D was used to find a best-fit conductor circumference and measure the diameter of the conductor in question.

Table 1 does not include results from scans taken from the simulated 110-foot (33-meter) centerline because they were not dense enough to be usable by the fit bent pipe tool. Similarly, in scenarios in which two scans were used from the 80-foot (24-meter) centerline, registered scans lacked sufficient density to be used by the same tool.

While two scans from the simulated 50-foot (15-meter) centerline proved dense enough for the fit bent pipe tool, there was insufficient overlap in the data to achieve readable results when both scans were taken 30 feet (9 meters, 31°) from the centerline, or 62° apart from each other. To achieve readable results at those angles from the 50-foot centerline, a second set of two scans had to be combined with the first set.

Similarly, two scans taken 10 feet (3 meters, 12°) on either side of the 50-foot centerline, or 24° apart from each other, contained insufficient coverage of the conductor for the fit bent pipe tool. The second set of two scans taken from the 50-foot centerline remedied this problem and produced readable results.

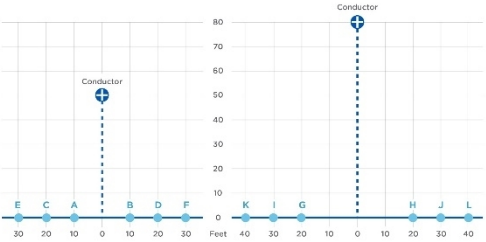

Figure 4: Scan points in relative relation to the measured conductors

Scan Points	AB	CD	EF	GH	IJ	KL	ABCD	CDEF	ABEF	GHIJ	IJKL	GHKL	ABCDEF	GHIJKL
Scans	504-507	508-511	512-515	516-519	520-523	524-527	504-511	508-515	504-507, 512-515	516-523	520-527	516-519, 524-527	504-515	516-527
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Table 1: Calculated measurement of conductor sizes from scans

Findings

Scans focused on conductors can be an effective way to measure conductor diameter, able to differentiate between and identify different types of conductors.

Manual registration of scans is often more effective than automatic registration for data preparation when measuring conductor diameter.

Measurements taken from 50 feet (15 meters) away required two scans to achieve the density needed to obtain the necessary data, making it the preferred option. Those taken from 80 feet (24 meters) required four scans to produce the necessary density. In comparison, scans taken from 110 feet (33 meters) did not have the density needed to complete the analysis, even with six high-density scans.

On measurements involving six scans, the process of stitching scans together resulted in enough noise to invalidate the results. For example, the combined data from six scans at 50 feet yielded results ignoring too much noise, while the scans at 80 feet yielded results that accepted too much noise.

Data registered using four scans had the most appropriate density without oversaturation or excessive noise in the data. Scan clusters of four scans taken at the 80-foot distance were within 0.2 to 0.5 inches (5 to 12.7 mm) of the conductor's actual diameter. Those taken at the 50-foot mark were within 0.1 inches (2.54 mm) of the actual diameter.

Best Practices

- High-density lidar scanning to measure a conductor's diameter is most effective when a conductor is elevated no more than 50 feet (15 meters). The conductors on most sites meet this parameter.
- Best results are achieved when scans are performed at approximately 15° and 25° angles from either side of the conductor.
- If a conductor is more than 50 feet (15 meters) in the air, consider using four scans to register the data. At lower heights, two scans may prove accurate enough to achieve desired results.
- Identify the possible conductors you are trying to match before conducting scans. If the potential conductors are very close in size, lidar scanning may be insufficient. However, if the possible conductors vary sufficiently in size, lidar scanning may be sufficient.
- To confirm the accuracy and increase confidence in the scanning process, similar scans could be performed using the same distances and methods on a known conductor in another area of the substation.