White Paper

ASSESSING THE VALUE AND EFFICIENCY OF VIRTUAL INSPECTIONS.

A comparative study of foot patrol and virtual inspections.

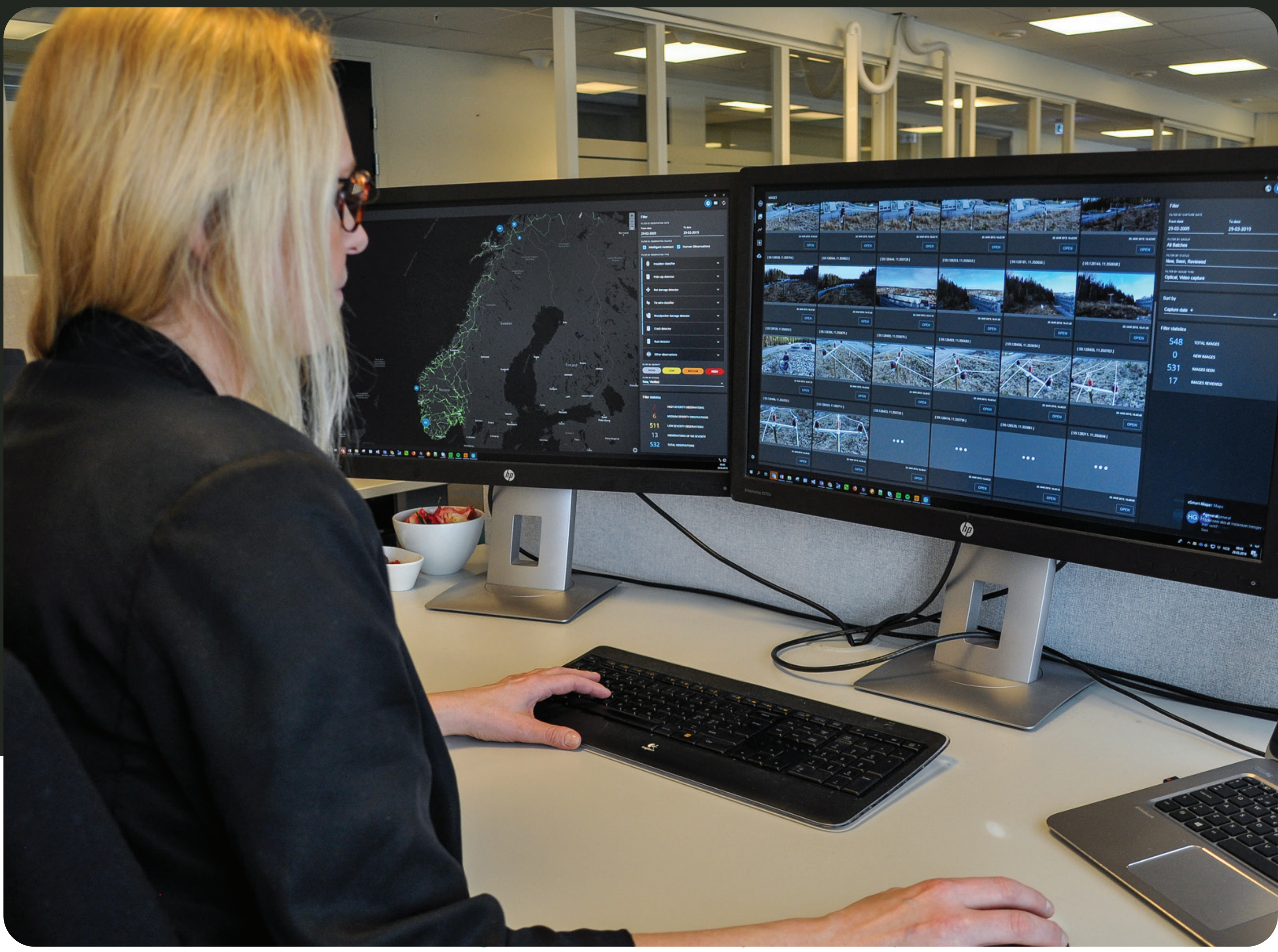
Content Page

Abstract

A comparative analysis of the effectiveness of imagery-based virtual inspections and foot patrols for overhead transmission lines was performed.

The findings demonstrate that imagery-based virtual inspections are effective and complement and extend the existing stack of inspection methods available to utilities for grid inspections.

The last quantitative comparison of inspection methods was an EPRI study in the 1990s.



Introduction

This white paper provides an overview of a comparative analysis of the effectiveness of two modes of visual inspection of overhead transmission lines, namely foot patrols and imagery-based virtual inspections. The analysis utilized data from Xcel Energy's inspection program. Xcel Energy's overhead transmission network consists of 22,000 miles of lines spanning nine states in the USA. The last quantitative comparison of inspection methods was an EPRI study in the 1990s. The next sections provide overviews of the virtual inspection and foot patrol methodologies.

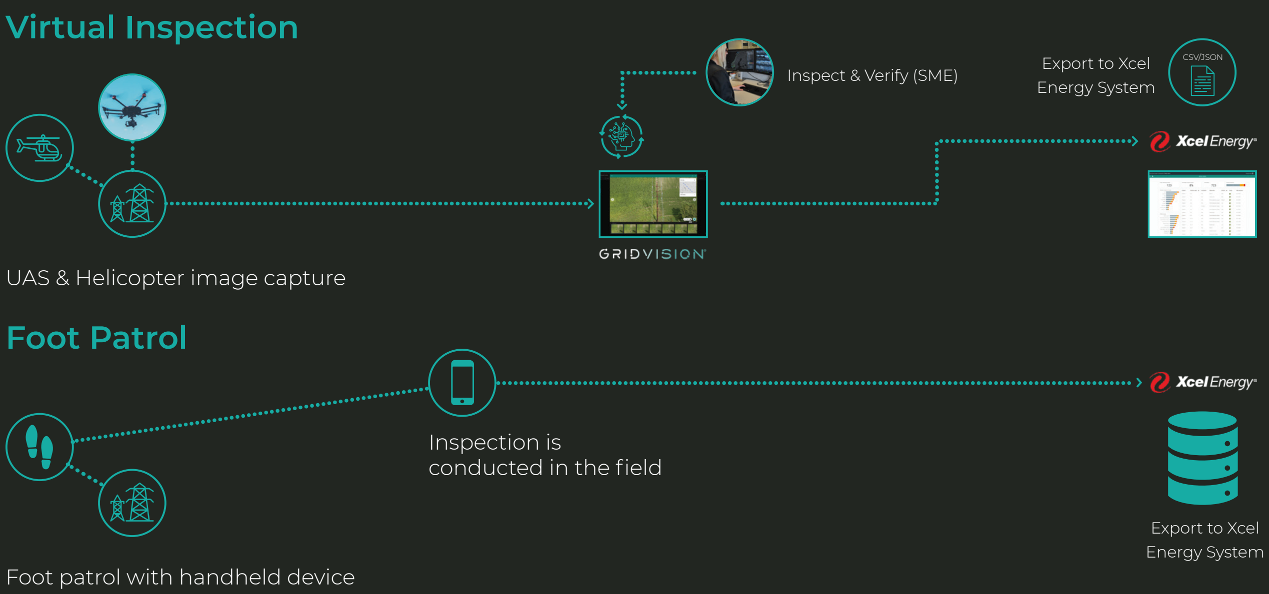
Overview of Virtual Inspection Program

Xcel Energy applies multiple inspection methods on its grid. In 2017 Xcel Energy in partnership with eSmart Systems and EDM International, Inc. (EDM) began robust virtual inspections of its entire transmission network. During the first four years of the ongoing program, Xcel Energy completed the first cycle of virtual inspections for its entire grid.

The virtual inspection process uses high-resolution images captured principally with unmanned aircraft systems (UAS), aka drones, with camera technology from PhaseONE operated by Phoenix Air Unmanned (PAU) and helicopters for certain areas. Once the images are captured they are imported and processed in eSmart Systems Grid Vision® inspection solution. The virtual inspections are then carried out by EDM's inspectors and the inspection results are exported to Xcel Energy's data and work management systems.

Overview of Foot Patrols

Xcel Energy has been conducting foot patrols (aka ground patrols) of the lines in its grid for decades and has established efficient processes. Foot patrols entail progressing along a row either on foot or by driving and inspecting the structures, conductors, etc. in a systematic manner. Xcel Energy inspectors view each structure from multiple angles often with binoculars and document their findings on their field computers. The inspection results are later downloaded into Xcel Energy's data and work management systems.



Overview of virtual inspection and foot patrol processes

Overview of Study

Study Objectives

The study focuses on the following objectives:

- Analyzing and comparing the inspection findings reported for foot patrols and virtual inspections.
- Assessing the effectiveness of virtual inspections for defect identification including confirming the presence of previously reported defects and closing out defects that have been corrected.
- Identifying general strengths and limitations of the two methods.

The study is based on actual data from Xcel Energy's inspection program.

Scope of Study

The study uses inspection data from 16 circuits comprised of voltage classes ranging from 34.5kV to 230kV. All circuits were assessed using both foot patrol and virtual inspection methods. Both inspections were completed within a window of 60 days or fewer to mitigate the risks of defects being corrected during the interval between the inspections. The inspections encompassed the same structures and components and were focused on identifying the same failure modes/defect types.

Assumptions

The following assumptions apply to the study:

- There is a negligible probability of new defects or changes is defect severity occurring within the above referenced 60-day window.
- The competencies of both the foot patrol and virtual inspection teams are similar.
- Neither the foot patrol nor the virtual inspection teams knew the data they captured would be used in a study.
- The line segments analyzed in the study were fully inspected using both methods.

Data Preparation

Significant time and effort was invested in preparing the data to ensure its validity and that it would provide the basis for credible apples-to-apples comparative analyses. Examples of the data preparation include the following:

- Removing types of failure modes usually excluded from both virtual inspections and foot patrols, but potentially present in historic reports (e.g., inspections to detect internal decay in wood poles etc.).
- Removing results of inspections focused on identifying upgrades and not related to maintenance issues.

Structures Inspected

The tabulated numbers of structures per voltage class that were inspected

Voltage Class	Number of Structures
34.5 kV	210
69 kV	239
115 kV	307
230 kV	159

Defect Categorization

Xcel Energy use a 5-level priority rating system when categorizing defects on its grid. Priority 1 is assigned to defects that require immediate action, priority 2 is assigned for items requiring near-term action, priorities 3 and 4 identify defects that can be addressed during scheduled maintenance and priority 5 defects are to be monitored.

Priority Rating	Description
P1	High Priority - immediate action required
P2	High Priority - action required
P3	Medium Priority - scheduled maintenance
P4	Low Priority - scheduled maintenance
P5	Low Priority - monitor

Results of the Comparative Analysis

Key Findings

Identification of New Defects

The results of the comparative analysis are summarized in the table below. The comparative analysis focuses on the number of new defects identified by foot patrol and by the virtual inspection.

	Priority Level	Foot Patrol New Defects	Virtual Inspection New Defects
Action Required	P2	1	3
Scheduled Maintenance	P3/4	117	170
Monitor	P5	143	247
Total		261	420

Based on these results, the **virtual inspections detected just over 60% more total defects than the foot patrols.**

Verification of Historic Defects

In addition, the virtual inspections verified the presence of a significant percentage of the historical defects in Xcel Energy's inspection records and found that others had been corrected or were invalid thereby highlighting the potential for virtual inspections to also be used for verification.

Virtual Inspection Verifying Historical Defects		
Priority Level	Corrected/ Invalid	Verified
P2	0	1
P3/P4	40	87
P5	3	157
Grand Total	43	245

Factors Impacting the Results

Two considerations are worth noting that may aid in interpreting the results:

- There is a large difference between the number of P5 defects identified by the foot patrols and virtual inspections, i.e., 143 defects compared to 247 defects, respectively. Several factors may have contributed to this difference, however, one has been verified, i.e., the field data collection system used for the foot patrols is cumbersome and data entry is time consuming. Hence, since P5 defects are only monitored, there could be situations when inspectors focus on reporting only P1 through P4 defects which are actionable and skip the entry of P5 defects.
- Certain types of defects are easier to detect during virtual inspections as the images are taken from above and enable top-down viewing of components and detection of defects that may be difficult or even impossible to see from the vantage points of a foot patrol. Likewise, certain types of defects are easier to detect during foot patrols. Examples of both types of defects are shown below.


Flashed Insulator

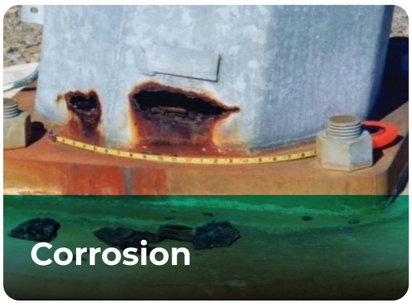

Rotten X-Arm


Broken Tie wire

Examples of defects that are easier to detect during a virtual inspection*

Examples of defects that are easier to detect during a foot patrol


Woodpecker Damage


Corrosion


Corrosion

Therefore, both inspection methods are relevant and add value, and utilities can choose when application of each method makes the most sense.

*These are examples of actual zoomed views of the high resolution imagery used during the virtual inspections, which can result in minor blurring.

Conclusion

Prior to this study the perceived benefits of virtual inspections have been based on anecdotal evidence from tens of thousands of inspections conducted over the last several years. In contrast, this study has produced quantitative confirmation that virtual inspections are quite effective when applied correctly with the right tooling, methodology, and expertise. Further, several of the findings are consistent with observations resulting from EPRI's landmark research on the effectiveness of various inspection methods during the 1990s, i.e., standardized inspection processes, inspector expertise and training, more time to view components, and easy-to-use data collection tools combine to yield better inspection results.

Virtual inspections vary in quality. The methodology, tools and SMEs utilized impact the quality of the results. The comparative analysis presented herein relied on the following:

- Foot patrols by Xcel Energy
- Virtual inspections by EDM International
- Images collected by Phoenix Air Unmanned
- Images captured by PhaseONE camera technology
- Grid Vision® inspection software by eSmart Systems

Virtual inspections represent an evolutionary step on the digitalization journey. They are not a replacement for foot patrols, rather they represent a valuable addition to the utility industry's inspection toolbox. When they are combined with other inspection methods the combined results represent better information and provide more insight into asset conditions than any one method can provide. Today, the utility industry is already benefiting from the application of this important new methodology, and it is anticipated that additional benefits will be realized as the enabling technologies (software, drones, AI) continue to improve.

White paper conducted by:

Xcel Energy · eSmart Systems · EDM · Phoenix Air Unmanned · PhaseOne