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Reporting on a Large Ocean Inlet Crossing Live Transmission Line Inspection Performed by LineScout Technology

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***Abstract* – This video summarizes a breakthrough in the emerging field of transmission line inspection and maintenance robots. Collaboration between electric utilities recently led to a robotic inspection of a large ocean inlet crossing transmission line, performed by LineScout Technology. Key challenges associated with the live line inspection and crossing of the suspension clamp are presented. Some of the findings revealed along the spans are shown. The accompanying paper also discusses some of the features of the robotic system that were found essentials for the success of the task.**

***Index terms*—Mechanical design, field robotics, telerobotics, power line inspection robot.**

I. Introduction

ROBOTIC applications has been introduced in several domains, to increase efficiency, ensure workers safety or realize tasks otherwise impossible to perform. The electrical power industry is also being infiltrated by robotics: several maintenance tasks present risks for the workers, clogged areas need to be inspected, and new sensors are being called upon to assess the condition of critical equipment.

Recently, a significant amount of interest was directed towards live power line inspection robots as several initiatives around the world were undertaken. Reference [1] is a recent survey paper that cites close to 80 references and identifies more than 40 active research teams in the field.

Furthermore, a growing number of power utilities now shows interest towards the introduction of some robotics in their mid term maintenance plans [2][3]. Although the time when robotics plays a regular role in power line maintenance may still appear very afar, it seems that a whole new field of applied robotics could be emerging in that direction.

The purpose of the featured video is to present a clear demonstration of this vision, since collaborative work between electric utilities recently resulted in the first reported complete visual inspection of a large ocean inlet crossing transmission line, performed on energized conductors by a robotic teleoperated system. This breakthrough reveals the potential of mobile robotics for power line maintenance. The accompanying paper describes the inspection task's specific challenges and key elements of the LineScout technology that were determinant for the success of the inspection.

II. The LineScout Robot and Inspection Task

The LineScout project, started in 2003, aimed at developing a teleoperated robot that would carry sensors onto energized transmission lines, to perform inspection and maintenance tasks. It has the ability to cross obstacles found on transmission line, thus enabling multi-spans applications.

The transmission line spans that were to be inspected are among the most spectacular in North America (see Fig. 1). It comprises six conductors about 15 m apart that spear over a water inlet for 1260 m until they reach the 100 m-high middle tower, erected on a peninsula. The second span is even longer, with 1690 m, until it ends at a supporting tower setup on a steep cliff. Access to the sites was possible with 4x4 high-clearance vehicles so the overall robustness and portability of LineScout was extensively validated.

Fig. 1. A mid tower on the 3.0 km crossing, LineScout in action

The LineScout control strategy, presented in [4], was also heavily tested as it behaved flawlessly during the entire day of operation. More specifically, the built-in interlock rules prevent the operator from any mistake and the Mode Operation Strategy (MOS) allowed him to safely focus his attention on the inspection task. Due to external conditions, some specific feedback channels were found essentials to

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ensure reliability by adjusting the course of the inspection:

- The real-time 3D virtual model, linked to the internal dual axis inclinometer, allowed the assessment of wind gusts effect on the robot lateral stability.
- Internal temperature of the traction wheels motor drives was closely monitored since it peaked above 47 ºC during the long and steep uphill phase (400 m, up to 16 degrees)
- Numerous telecommunications antennas in the vicinity degraded the RF data link in some sections of the spans. By monitoring a Data Transmission Quality Index, based on the count of completed communication cycles per second, the operator was always confident to pursue and eventually traverse the challenging sections.

As presented in [5], the geometrical design of the robot architecture allows up to four different crossing strategies to adapt with sequences of obstacles. This was helpful since the crossing of the 0,72 m long suspension clamp was complicated by the steep slopes and the several consecutive vibration dampers located on each side. Even more challenging was the fact that the two spans are not aligned in a vertical plan but present a horizontal change of direction of 7 degrees. In this case, the built-in mechanical compliance allowed the LineScout structure to accommodate for this. The following features were recently implemented or refined for the success of the inspection.

- Addition of an inspection camera with 26X optical zoom and high frequency image stabilizer. Based on past inspections when viewing towards the sun, aperture manual control was enabled.
- Addition of an infrared (IR) camera for the inspection of energized components since excessive heat generation is sometime symptomatic of malfunction.
- Addition of a Global Positioning System (GPS), validated for live-line work, and improvement of the wheel odometer reading to include the effect of slope climbing or conductor wire diameter. These two additions were meant to precisely localize any findings, within a few meters.
- Modeling of the power consumption for each phase: up or downhill travelling, inspection, obstacle crossing, power saving “sleep” mode, etc. This was crucial to establish a reliable estimate of the battery autonomy during the 6-hour job. Experimental results were within 3% of the modelling.

III. Results & Conclusion

The energized installation and removal of the LineScout was conducted smoothly by line maintenance technician using a custom method inspired by standard practices. To some extent, the inspection robot was considered as a new tool of their toolset.

The inspection was performed without any malfunctioning of the LineScout and provided high value images of line components and area of interest. Several hours of raw footage are thus archived and available for line maintenance personnel’s future evaluation. Of the newly introduced features, the manual control of aperture and the image stabilizer were among the most appreciated. This allowed maintenance personnel to follow closely the inspection, and actually assess remote components condition, on adjacent conductors or up in the towers.

No defect was expected since traditional means of power line inspection (helicopter patrol, binoculars from ground, etc.) did not identify any. However, collected images gave clear indications that several sections of the adjacent conductors deserve further investigations. The final inspection report is likely to help planning the next phase, since optimal maintenance decisions require actual data.

The reported experiment demonstrates the feasibility of using mobile robotics for live transmission line maintenance. In addition to the capacity to circulate on the line and cross obstacles, features like robustness and compatibility with usual line maintenance work methods were key to consider.

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