“Ti” EPRI Transmission Line Robot Development – Executive Summary

Overview

Overhead transmission lines are among the utility industry’s most widely distributed assets, traversing tens of thousands of miles, often in remote locations. Reliability requirements, component aging, clearance and right-of-way inspection compliance drive the need for thorough, timely inspections along the entire length of these lines. Such comprehensive assessments by maintenance personnel, working on the ground or in aircraft, currently entail significant expense.

To expand inspection capabilities and increase cost-effectiveness, the Electric Power Research Institute (EPRI) is developing a transmission line inspection robot to be permanently installed on, and designed to traverse 80 miles of line at least twice a year, collecting high-fidelity information that utilities can act on in real time. As the robot crawls along the transmission line, it identifies high-risk vegetation and right-of-way encroachment and assesses component conditions by means of various inspection technologies.

After an initial concept design, the EPRI research team refined the design developed a prototype robot. That robot, nicknamed “Ti,” has been put through a series of tests at the EPRI lab in Lenox, Massachusetts and data is being compiled that will lead to further refinement of the design in the coming years.

The Robot in Action - Video Links

Videos have been created to show Ti as it has gone through testing at the EPRI lab. You can follow these links to the EPRI YouTube page where these videos are posted.

Development of a Transmission Line Inspecting Robot – January 2011; 4:57 running time
http://my.epri.com/portal/server.pt?open=512&objID=243&&PageID=236090&mode=2&in_hi_userid=95399&cached=true

Initial Concept Video of Transmission Line Robot Project; 5:42 running time
http://my.epri.com/portal/server.pt?open=512&objID=243&&PageID=236090&mode=2&in_hi_userid=95399&cached=true

Features and Functionality

Ti has high-definition visual and infra-red spectrum cameras with advanced image processing to inspect the right-of-way and component conditions. It will be able to determine clearances between conductors, trees, and other objects in the right-of-way. The cameras also will be able to compare current and past images of specific components to identify high-risk conditions or degradation. As an alternative to the camera, the robot may be equipped with a Light Detection and Ranging (LiDAR) sensor to measure conductor position, vegetation, and nearby structures.

Ti will transmit key information to utility personnel, with a global positioning system accurately identifying its location and speed. Another system will collect data from remote sensors deployed along the line, and an electromagnetic interference detector will identify the location of discharge activity, i.e. corona, or arcing. Where discharges are identified, field personnel may do further inspections using daytime discharge cameras.

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The conductor-crawling robot has been designed to work with a variety of EPRI-developed radio-frequency sensors that can be placed along transmission lines to provide real-time assessment of components such as insulators, conductors, and compression connectors. These sensors will likely be deployed in areas of environmental stress or where specific component types have been installed. For example, lightning sensors will be installed in high-lightning areas, vibration sensors will be used in high-wind areas, and leakage-current sensors will be deployed in coastal areas to detect salt contamination.

The deployed sensors will collect data continuously, develop histograms, and determine maximum values. Cached and current data will be transmitted to Ti when it is in close proximity and will then be transmitted to maintenance personnel. The inspection robots, when coupled with these sensors, will be able to provide comprehensive, accurate, and useful information to optimize line maintenance and improve transmission reliability. In some cases, the purchase of robots for use in place of maintenance crews could shift O&M expenses to capital costs, allowing a return on investment and depreciation.

The transmission line robot is permanently installed on a transmission line shield wire. It traverses structures and obstacles, e.g. marker balls, utilizing bypass systems that are permanently installed on the transmission line. The robot automatically disconnects itself from the shield wire and connects itself to the bypass system. Once it is has bypassed the obstacle or structure it then returns to the shield wire. These bypass systems are installed at the time construction or may be part of the line hardware itself. It is envisioned that in years to come the Ti's mobility could be developed further to remove the need for these by-pass systems enabling is deployment on existing transmission lines.

Although Ti may be permanently installed on long transmission lines it can be relocated if required to other transmission lines or it may move from one line to another utilizing a bridge that is installed on nearby structures.

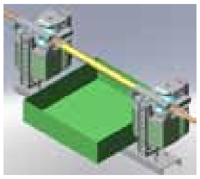
The current version of the robot is being designed to inspect an average of 12 765kV structures and spans per day. The robot is also capable of moving up to five miles per hour if it needs to reach a portion of the line more quickly, for instance if it needs to inspect a line outage. The robot moves along the shield wire and gets energy through power harvesting which it stores in onboard batteries.

Ti has been designed to inspect a number of things including right-of-way vegetation, right-of-way encroachment, component condition and it also collects remote sensor data.

Stages of Transmission Line Robot Development

EPRI is in the middle of a research, development and demonstration project that started in 2008 and is being targeted to result in a field implementation in 2014.

Concept – Initial requirements for the robot developed based on industry knowledge and feedback from utilities. The bypass system, solar panels, sensor package and power requirements were a key emphasis in the concept development design.



Design – A detailed design was performed of both the robot and the bypass systems. Details of mobility as well as the integrated sensor, control and communications package were developed.

Technology Demonstration – Technology demonstrators of both the bypass systems and the mechanical components of the robot were constructed, tested and refined. Testing was performed on indoor short sections of line with bypass systems installed.

Full Scale Laboratory Testing – A test loop was developed where all the challenges that the technology demonstrator robot would encounter on a typical 765kV line were simulated (angles and inclination). Bypass systems were developed for each of the challenges, and then refined and installed. The robot was then tested and evaluated as it faced each of the challenges.

Remote RF Sensor – A suite of RF interrogated sensors has been developed to continually assess the condition of components and transmit to Ti when it is in close proximity. Leakage current, conductor temperature, vibration, lightning and fault sensors have been developed and are currently being demonstrated at 12 different sites.

Bypass System – The Heart of the Technology

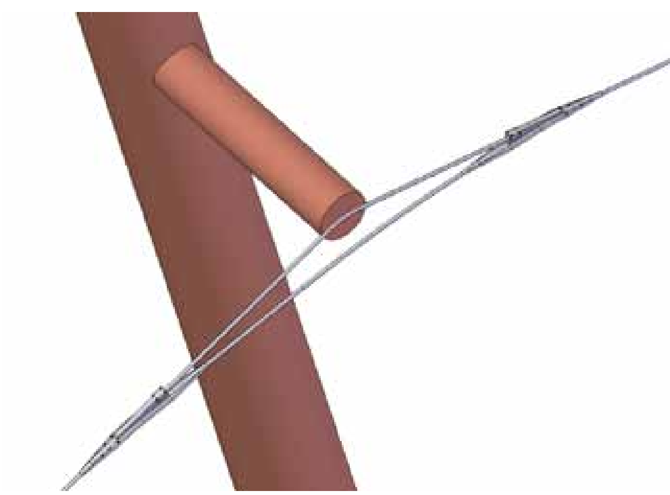
One of the great challenges in developing the robot was creating a design that would allow it to move along the shield wire of transmission lines and be able to move past a structure or other obstacles in its inspection path. Ti utilizes bypass systems that are permanently installed on the structure and around objects.

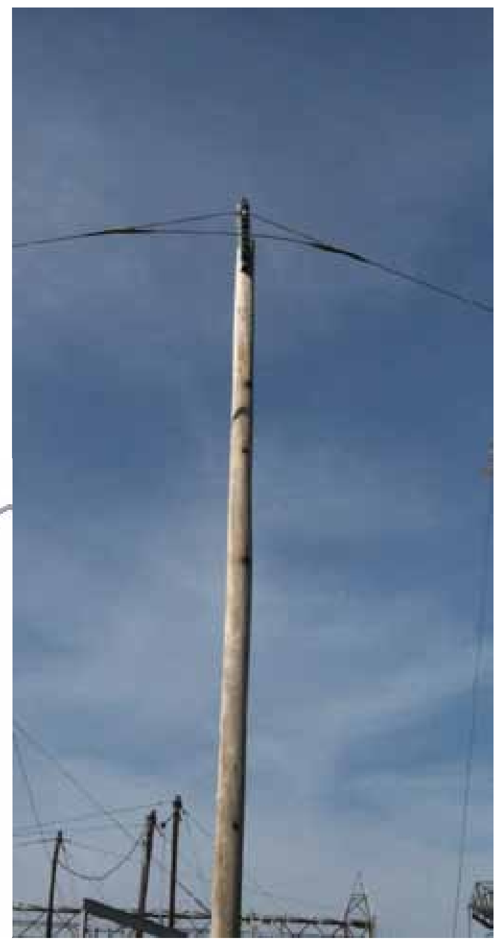
EPRI is currently testing six different bypass systems to make this possible. These bypass systems make use of an additional short section of shield wire that allows the robot to avoid the tower structure and any obstacles allowing it to make its way to the next segment of the transmission line. These may be in addition to the normal line hardware or built into the normal line hardware.

By utilizing the bypass system methodology, Ti is able to bypass structures with confidence and no operator input. For new transmission lines the cost of the additional or modified hardware is negligible compared to the overall cost of the transmission line.

Development of Test Site

In order to validate the performance of the robot and the bypass systems through the development process, a test site has been constructed at the EPRI Lenox, Mass. laboratory. The test site, or “Loop” as it is called, simulates the most challenging situations that the robot would see on a 765kV transmission line shield wire. A range of angles and inclination combinations as well as different configurations were designed into the Test Loop.

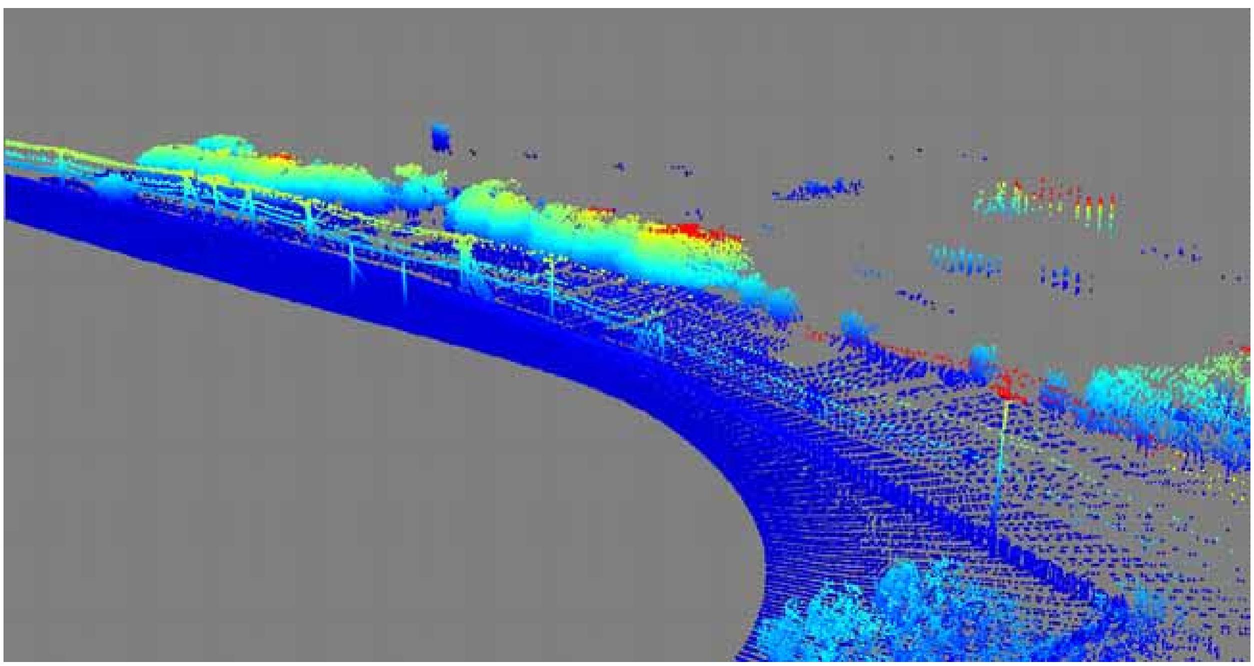




Review of Ti Robot Performance and Findings

Mobility: Technology demonstrators for both the robot and the bypass systems have been built and undergone a series of tests both indoors and on the Loop. The technology demonstrator robot was able to navigate all of the challenges of the test loop multiple times without operator input. Important insights were obtained which will result in design improvements, and data was gathered on the power usage and battery performance.

Sensor Package: A suite of four remote RF sensors from which the robot will collect data have been developed and are currently being tested at 12 utility test sites ranging from 138kV to 345kV. Numerous lessons have been learned which will result in new improvements and developments for the robot. Testing of the LiDAR sensor from the moving transmission line robot has been performed and initial results show great promise. Below is an example of an image generated by this sensor.



In this image, colors represent the height above ground – the LiDAR measured the distance from the robot using the laser, then with the knowledge of the location works out the height of the objectives above ground.

A detailed sensor and control system architecture has been developed and in currently being implemented. It will be tested and then finally integrated into the robot itself.

Next Steps in Development

Utilizing the knowledge gained from the Loop testing, the next generation of robot and bypass systems is being designed and implemented. Testing of the new design is scheduled for the summer of 2011.

Development of the remote sensors, LiDAR, image recognition and other sensors continues. These sensing systems will continue to be tested and evaluated on utility test sites.

The control and sensing system architecture is being implemented and will be tested in 2011.

EPRI is working with American Electric Power (AEP) engineers with the objective of including the robot and bypass systems in their next 765kV transmission line to be built in 2014.

Technical Expert

Andrew Phillips, Director of Transmission and Substation Research, is the key technical contact for this project.

About EPRI

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together experts from academia and industry as well as its own scientists and engineers to help address challenges in electricity generation, delivery and use, including health, safety and the environment. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

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