Ground Based Robots & the Future of Applications of Robots for Transmission Line Work

2015 Minnesota Power Systems Conference

Bryan Rushing and David Elizondo
November 10-12, 2015
Agenda

1. Current Types of Robots Available in the Industry
2. Past Experience with Ground Based Robots
3. Basics of Robots Suspended from line
4. Basics of Unmanned Aerial Vehicles (UAV or UAS)
5. Methodology to Estimate Benefits of Energized Work
6. Future of Transmission Line Robotics
Current Robot Technologies

- **Ground Based -** Designed to remotely capture and control energized conductors and operate in contact with the ground
  - Used for at least 10 to 15 years, proven technology for utilities
  - Perform heavy duty, maintenance and construction tasks, beyond human capability and designed to act as temporary transmission line structures, among other duties

- **Robots Suspended from the line -** Designed to serve as the extended eye and arms of the transmission lineman
  - Used for at least 5 to 8 years, proven technology for a number of utilities
  - Designed as a mobile platform, to perform visual inspections and light duty maintenance tasks
Current Robot Technologies

- Aerial Based - Designed to serve as the extended eye of the transmission lineman
  - Used for at least 5 years (Outside North America, under R&D initiatives)
  - Designed as a mobile platform, to perform visual inspections

- Other Robots
  - Climbing robots and Insulator robots
Ground Based Robots

- **Line Master™**
  - Design Principle: Remotely handle, move and relocate energized conductors of different voltages.

- Specifically designed to address heavy duty tasks:
  - Live line procedures such as the replacement of rotten poles utilizing the existing hole (especially in rock)
  - Reframing and re-insulating of structures which are typically difficult to execute with traditional live line tools like hotsticks.

- **Hydraulic Remote Control**
  - Control of the insulated arm is via hydraulic power from a remote hydraulic power source

* Technology protected by US Patent

Copyright. Quanta Services. 138 kV Tangent Structure, Chicago, US
Robot Applications

- Structure repair, replacement and temporary support.
- Replacement of insulators
- Reconductoring of lines
- Replacing line spacers
- Adding circuits to structures
- Selective substation repairs at energized base load generation plants, including nuclear plants
- Other miscellaneous maintenance tasks
Success Stories of Ground based Robots

Overview of the transmission corridor and three ground based robots in operation.
Example 1: BG&E Transmission Tower Inspections

- 50 transmission lines & 400 different locations in the transmission line infrastructure required inspection at 115 kV, 230 kV and 500 kV.
- Despite starting this work de-energized, due to a tight time frame, BG&E decided to explore the alternative of executing this work energized.
- BG&E could provide up to 10 non-reclose requests per day and a team consisting of QES qualified 3-person field crew plus a team lead could inspect up to 10 transmission line locations a day and thus finish the tasks in a two months time frame.
- Breakdown of estimated avoided cost of 11.9 MUSD by performing work energized
  - Redispatch/Production cost (51%, 6.1 MUSD)
  - Congestion Revenue Loss (48%, 5.7 MUSD)
  - Savings in man power (1%, .10 MUSD)
- Taking 50 transmission lines out of service consecutively in the BG&E system would have required a different dispatch strategy, would have created stress on the remaining system and made the overall system more congested and vulnerable. Therefore, a non-energized solution was just not acceptable.
Success Stories of Ground Based Robots

Example 2: Transmission line structure replacement for Florida utility

- The main scope of this project was the replacement of the structure of a 230 kV single circuit transmission line that was built in the early 1970’s while the transmission line remained energized.

- The new structures were installed over a distance of 21 miles. The new and improved transmission line tower design consisted of a single steel pole, with one circuit on each side of the structure in a vertical conductor configuration. The new design used the existing right of way and reduced the footprint of the tower base compared to the older H-frame design.

- Breakdown of estimated avoided cost of 7.5 MUSD by performing work energized
  - Redispatch/Production cost (63%, 4.7 MUSD)
  - OASIS Reservation (43%, 3.2 MUSD)
  - Savings in man power (-6%, 0.45 MUSD) *

- Value at Risk
  - Associated with reliability which may result in penalties of 0.6 to 24 MUSD

* The savings in man power are negative because in this particular example it takes more time to replace structures in the energized mode.
Success Stories of Ground Based Robots

Example 3: Case: 88-kV Energized Transmission Re-conductoring for Johannesburg City Power

As a result of the award of the 2010 World Cup event in South Africa, Johannesburg City Power decided to improve their transmission transfer capability and network reliability, and to explore innovative techniques to rebuild their transmission circuits by replacing the existing conductors with high capacity composite core conductors.

The main scope of this project was the re-conductoring of existing 88 kV transmission lines to increase by a factor of two the power transfer capability (from 100 MVA to 200 MVA) and improve customer satisfaction and reliability while the existing circuits were energized and utilizing the existing transmission structures.

Breakdown of estimated avoided cost of 18 MUSD by performing work energized

- Savings in man power (-10%, 1.9 MUSD)
- Savings in Service Interruption Penalties (110%, 20 MUSD)

This work could not be executed de-energized due to the fact the 88 kV transmission line were significantly loaded and the utility’s inability to shed load for such long periods of time.

Overview of main transmission corridor and robotic arms
Johannesburg, South Africa
Current Robot Technologies

- **Ground Based** - Designed to remotely capture and control energized conductors and operate in contact with the ground
  - Used for at least 10 to 15 years, proven technology for utilities
  - Perform heavy duty, maintenance and construction tasks, beyond human capability
  - Designed to act as temporary transmission line structures, among other duties

- **Robots Suspended from the line** - Designed to serve as the extended eye and arms of the transmission lineman
  - Used for at least 5 to 8 years, proven technology for a number of utilities
  - Designed as a mobile platform, to perform visual inspections and light duty maintenance tasks

- **Aerial Based** - Designed to serve as the extended eye of the transmission lineman
  - Used for at least 5 years (Outside North America, under R&D initiatives)
  - Designed as a mobile platform, to perform visual inspections
Robots Suspended from the line

- Different proven technologies
  - Canada (IREC and Hydro Quebec)
  - Japan
  - USA (EPRI)
  - Brazil
  - China

- Design Principle: Move over live or ground transmission line conductors and overcome “obstacles” such as suspension clamps/insulators

- Specific applications
  - Detailed inspections of transmission line components (cable, dampers, etc.)
  - Specialized cameras
  - Corrosion detection
  - Insulation cleaning

- Remote Control
  - Control by a ground operator
Sample of robots suspended from the line, live conductor

LineScout robot in operation [1]

Expliner robot in operation [2]
Sample of robots suspended from the line, live and ground conductor

TI robot using the by-pass system of the ground wire (lab experiments) [3]

Robot for corrosion detection applications that travels on live conductors [4]
Sample of robots suspended from the line, live and ground conductor

Robot for installing warning spheres that travels on the ground conductor [5]

Robot for insulation cleaning applications [6]
Current Robot Technologies

- **Ground Based** - Designed to remotely capture and control energized conductors and operate in contact with the ground
  - Used for at least 10 to 15 years, proven technology for utilities
  - Perform heavy duty, maintenance and construction tasks, beyond human capability
  - Designed to act as temporary transmission line structures, among other duties

- **Robots Suspended from the line** - Designed to serve as the extended eye and arms of the transmission lineman
  - Used for at least 5 to 8 years, proven technology for a number of utilities
  - Designed as a mobile platform, to perform visual inspections and light duty maintenance tasks

- **Aerial Based** - Designed to serve as the extended eye of the transmission lineman
  - Used for at least 5 years (Outside North America, under R&D initiatives)
  - Designed as a mobile platform, to perform visual inspections
Sample of UAV Technologies

■ Industry trends
  • Unmanned Aerial Vehicles, (UAVs) are growing

■ Potential applications
  • Replace human tower climbing inspections for comparable results

■ Industry barriers
  • FAA or Transport Canada regulations
  • Certificate of Authorization

Microdrones (Germany)

DragonFly (Canada)

Courtesy of Virginia Tech (USA, Yamaha UAVs)
Sample of UAV Technologies

- Technology transfer
  - First used in military applications
- Potential applications
  - Assess transmission infrastructure “state” after a major natural event
  - Assess transmission line construction progress
  - Comparable results
- Industry barriers
  - FAA or Transport Canada
Quantifying Economic Benefits: Case Study 1

- Transmission line structure replacement
- Breakdown of 7.5 MUSD
  - Redispatch/Production cost (63%, 4.7 MUSD)
  - OASIS Reservation (43%, 3.2 MUSD)
  - Savings in man power (-6%, 0.45 MUSD) *

- Value at Risk
  - Associated with reliability which may result in penalties of 0.6 to 24 MUSD

* The savings in man power are negative because in this particular example it takes more time to replace structures in the energized mode.
What is the future?

We are all “believers” of robotic applications for transmission line work.

Each robotic technology has specific applications, advantages and disadvantages.

At the end of the day, it is all about the business value and the business case.
Thank You for Listening!

Quanta Technology, LLC
4020 Westchase Boulevard, Suite 300
Raleigh, NC  27607 USA
Tel: + 1 919-344-3000
www.quanta-technology.com