
Welcome to this CIGRE UK Webinar
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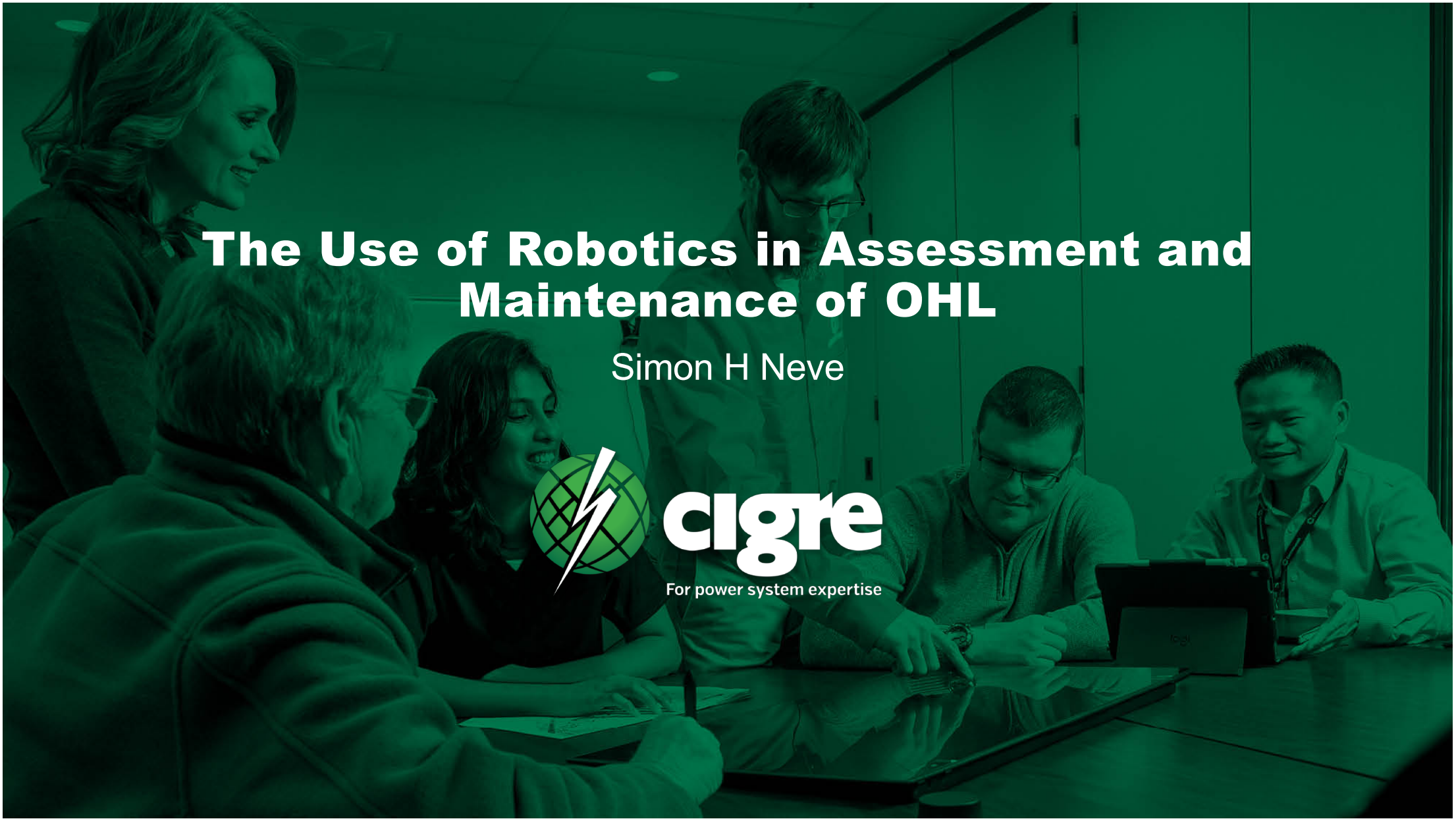

The Use of Robotics in Assessment and Maintenance of OHL

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The Use of Robotics in Assessment and Maintenance of OHL

1. Introduction
2. Review of Existing and Developing Robotic Technologies
   - Line Suspended Robots
   - Unmanned Aerial Vehicles (UAV)
   - Ground Based Robots
   - Other Types of Robots (Climbing Robots, Insulator Robots)
3. Practical Considerations for Selection of Robots
4. Value and Benefits of Robotics
5. Future Applications of Robotic Technologies
6. Gaps in Knowledge and Challenges
7. Conclusion

Introduction

- Many robotic technologies presented here were published in previous CARPIs (Conferences on Applied Robotics for the Power Industry)
- Robotic technologies have already proved to be a valuable means of inspecting OHLs
- A few major electric utilities have already introduced robotics into their maintenance practices, and several are funding projects to do so
- Safety, efficiency, reliability and availability of OHLs are the main factors driving this trend
- The expected increase in live-line work approaches has stimulated the development and use of robotic devices
  - Minimize risk to field personnel safety and maintain power system reliability

Introduction

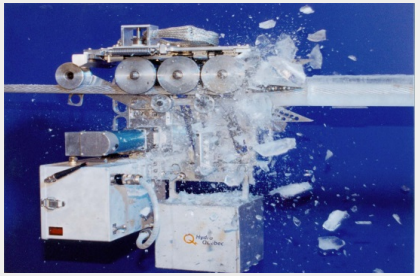
- For many electric utilities:
- OHTLs are ageing
- Requirements for OHTL outage availability + reliability are very high
- The actual condition of line components and their remaining lifetime are characterized with significant uncertainties and gaps in knowledge
  - Conductor is generally considered as the most important line component as it contributes to about 30% of total capital investment
  - Ageing and degradation mechanism (corrosion, fatigue and thermal aging)
  - Degradation curves of ACSR conductors ?
- Aged lines
  - Need to define remaining RTS of conductors without taking a sample
  - Loss of steel cross-section due to corrosion ?
  - End of life of ACSR ?

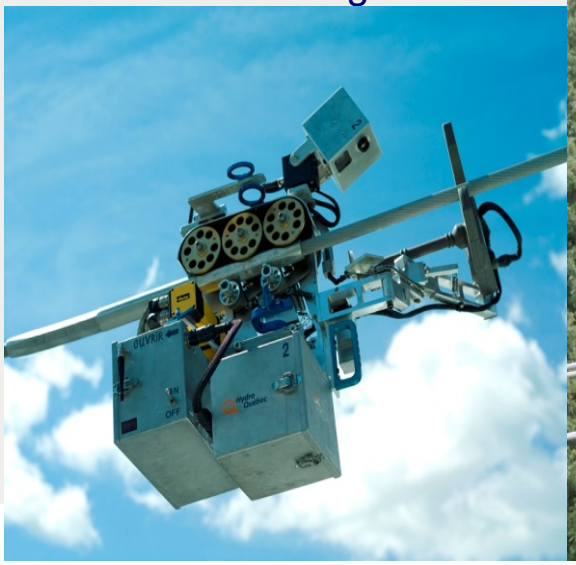
Line Suspended Robots

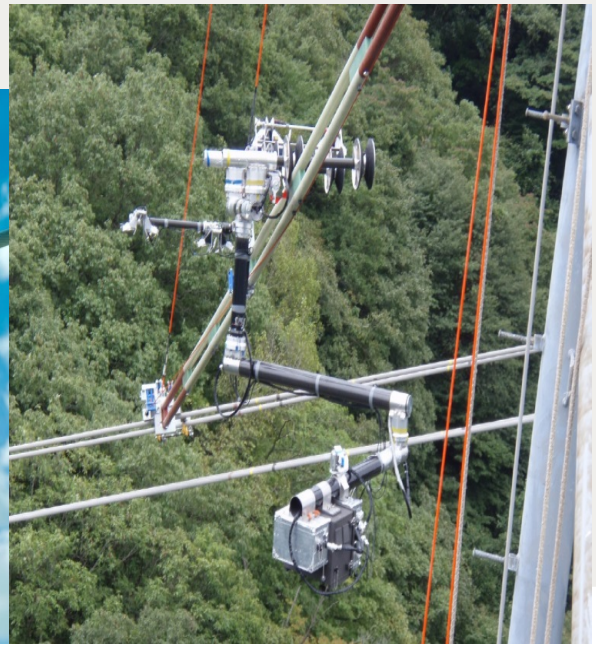
- Robots that are suspended from the line and designed to serve as the extended eyes and arms of the transmission lineman
- Their basic design function is to perform visual inspection but some of them could perform maintenance tasks too (e.g. conductor repair)

Line Suspended Robots (I)

- Inspection and Maintenance Tasks:
  - Splice Condition Assessment (electrical resistance measurement)
  - Visual Inspection
  - Infrared Inspection
  - Temporary Repair of Broken Stands
  - Torque Wrench for Bolted Assembly
  - Vibration Damper Retrieval
  - Conductor De-Icing

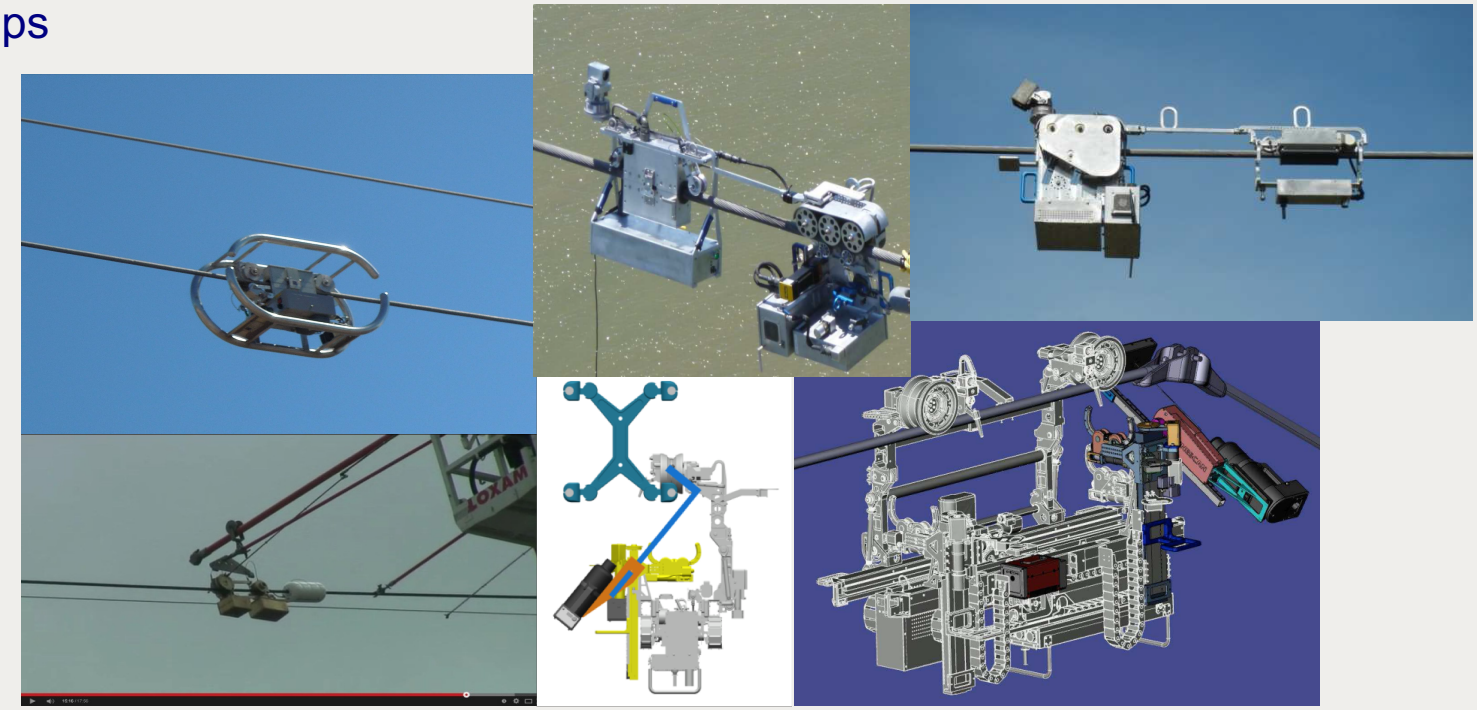






Line Suspended Robots (II)

- Assessment of conductor condition with NDT sensors
  - Corrosion detection sensors for zinc coating or steel cross section
  - Portable X-ray system: internal broken strands inside suspension clamps



Unmanned Aerial Vehicles

- A power-driven aircraft, other than a model aircraft, that is designed to fly without a human operator onboard
- Primarily designed to perform visual inspection
- Increasing interest to electric power utilities, as this work is performed while the transmission lines are energized

Unmanned Aerial Vehicles (I)

- Electric power utilities are interested in investigating the technology of UAV's as it provides a unique perspective
  - They fly close to transmission lines
  - The work is performed while the transmission lines are energized
- Development of UAV's is very active as more and more prototypes are being built
- Three types of UAV:
  - Fixed-Wing Aircraft
  - Helicopter
  - Multicopter
- For each type of UAV, the TB gives:
  - General Description
  - Operating Range (weight, dimensions, payload, etc.)
  - Useful Applications in Overhead Lines Maintenance

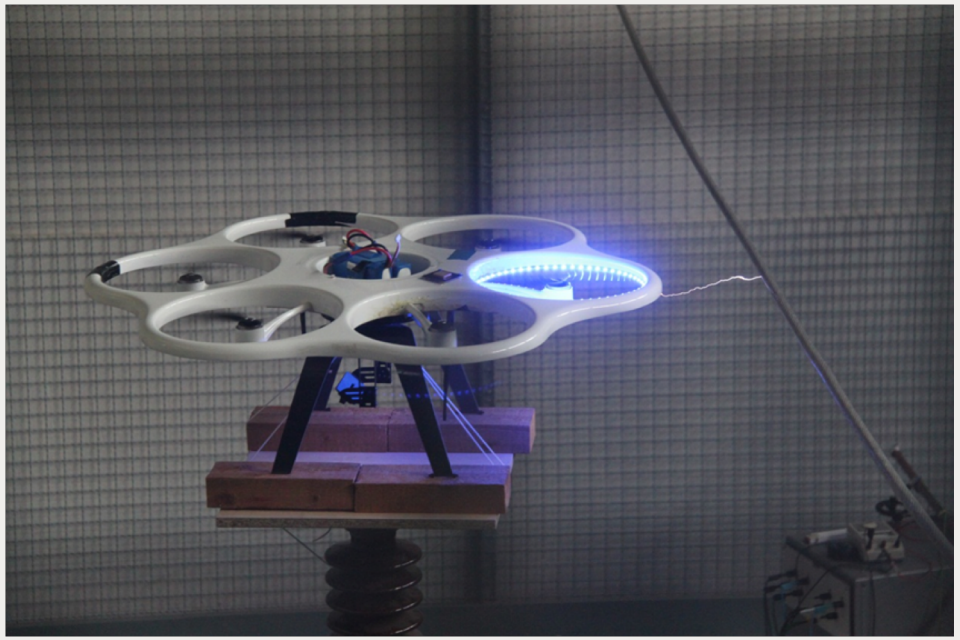
Unmanned Aerial Vehicles (II)

- Best UAV type according to each maintenance activities

Fixed-Wing Aircraft	Helicopter	Multicopter
Fast recognition in case of break-down	Intensive inspection in long section of OHL (75 towers per day). RGB videos, corona inspection, IR inspection.	Specific inspection in any component of OHL (1 or 2 towers per day). RGB videos, corona inspection, IR inspection.
LIDAR applications. Topography and vegetation managing	Pilot cable laying	

Unmanned Aerial Vehicles (IV)

- Requirements for high voltage interference testing, such as electric field test, magnetic field test, transient field test, etc.



High voltage AC-test of a multicopter with a pre-discharge between phase conductor and multicopter housing

Unmanned Aerial Vehicles (V)

- Regulations for using UAVs vary from one country to another
  - According to different country regulations, operators must maintain a clear visual line of sight (VLOS) at all times
    - ✓ In the US, the Federal Aviation Administration (FAA) has approved BVLOS in a few test cases
    - ✓ Transport Canada is currently developing test ranges for BVLOS
- Risks of UAV commercial operations
  - Using poorly manufactured UAVs
  - Unlicensed operators without operating procedures
  - Unregulated flights without Federal approval
  - Invasion of privacy
  - Safe electrical distances using UAVs without flashovers
  - EMF/EMI effects on UAVs

Ground Based Robots

- Robots that are designed to remotely capture and control energized conductors
- They are used for transmission structure repair and replacement, insulator replacement, replacing line spacers, etc.

Ground Based Robots

- They execute tasks that are far beyond human capability from a mechanical and electrical stress perspective
- The main benefits :
  - Increase safety to field personnel
  - Minimize the risk to power system reliability when performing live-line work
- Mature technology for more than 15 years

Ground Based Robots

- Practical considerations for live-line work

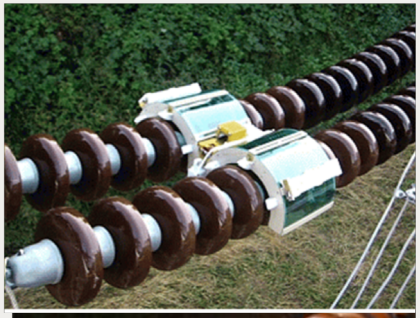
Ref	Factor	Factor Description
1	Safety	Safety considerations for the job.
2	Maintenance activity	Specific task to be executed (structure replacement, re-conductoring, etc.)
3	Infrastructure condition	The condition of the transmission infrastructure, for example, age.
4	Asset owner savings	Energized work enables the work to be performed when needed without an outage required, for an optimal use of mobilized equipment and crews as jobs could be done in succession.
5	Reliability	The impact of an outage on the overall system reliability. Common metrics used are: congestion, unserved energy, loss of load probability, cost of serving load, nodal and zonal locational marginal prices (LMPs).
6	Public Image	Energized work does not disrupt customer service
7	Switching Risk	Prevents the risk of wrong switching due to grounding requirements
8	Less Accidents	The historical records around the world have shown that work under energized conditions have no safety incidents

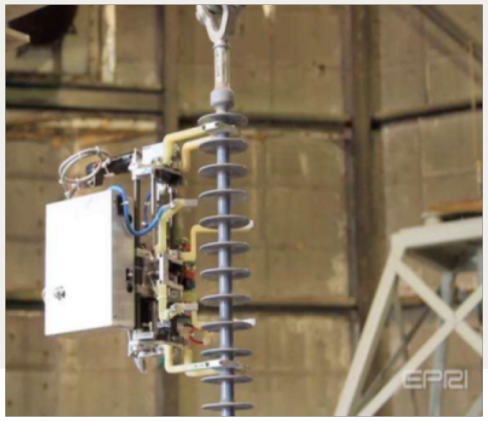
Other Types of Robots

- Climbing Robots
- Insulator Cleaning Robots
- Insulator Inspection Robot
- etc.

Other Types of Robots

- Live-line Insulator Cleaning Robot
- Live-line Insulator Inspection Robot
- Insulator Crawling Robot
- Snake-like Robot Inspecting Insulator
- Climbing Robot





3. Practical Considerations for Selection of Robots

Considerations	Line Suspended		Other	UAV	Common Evaluation Method
	Energized	De-energized			
Mechanical Considerations					
Conductor Diameter Range	X	X			Analysis
Traversing Splices	X	X			Testing
Traversing Dampers	X	X			Testing
Traversing Structures	X	X			Testing
Conductor Inclination ±	X	X			Testing
Environmental Considerations					
Operating Temperature Range	X	X	X	X	Testing / Analysis
Operating Wind speed Range	X	X		X	Analysis
Operating Humidity Range					Testing / Analysis
Electrical Considerations					
Minimum Approach Distances	X		X	X	Analysis
Corona Performance	X		X	X	Testing
Corona Immunity	X		X	X	Testing
Local Arcing Immunity	X		X	X	Testing
Ability to withstand arc to robot	X		X		Testing
Electric Field	X		X	X	Testing
Magnetic Field	X		X	X	Testing
Ability to withstand Switching and lightning surges	X		X		Testing
Communication Considerations					
Comply with RF standards	X	X	X	X	Analysis
Redundant /Failsafe communications	X	X	X	X	Analysis
Installation / Removal Considerations					
Ability to install/remove energized	X				Demonstrate
Ability remove if some/all electronics fail	X	X			Demonstrate

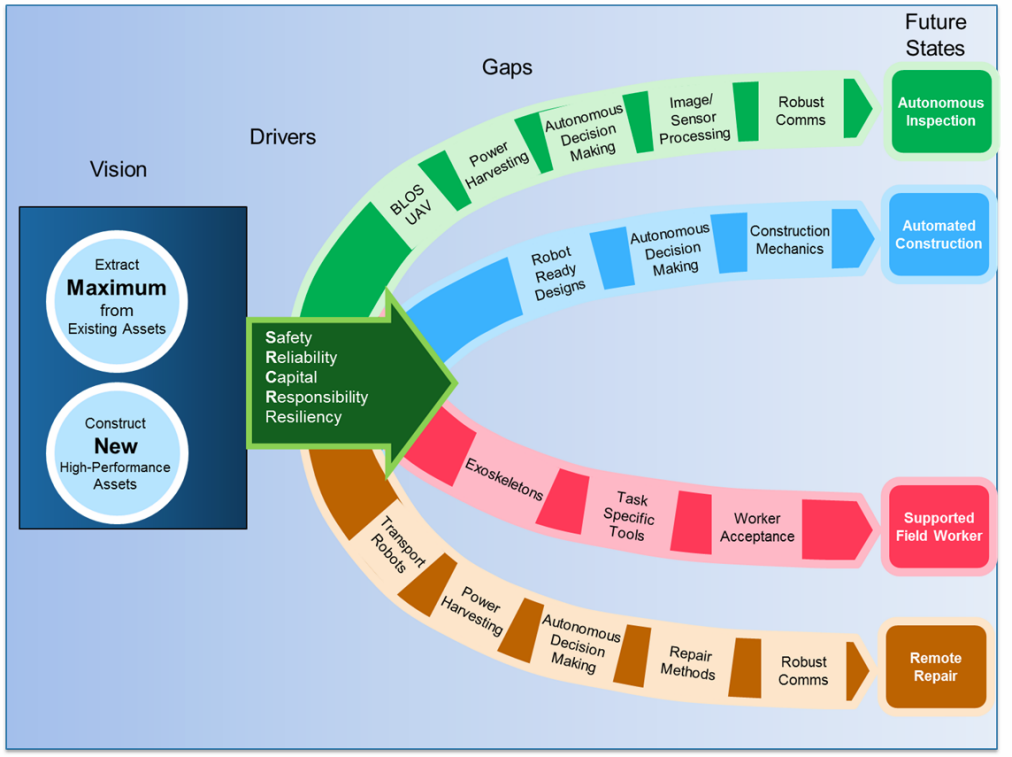
4. Value and Benefits of Robotics

- **Reliability** of the network: introduction of state-of-the-art inspection technologies into maintenance practices
- Equipment **sustainability**: better condition assessment and monitoring, resulting in optimal maintenance decisions
- Equipment **availability**: new possibilities in live-line work
- Workers **safety**: remote live-line work, access to conductors and ground wires
- Allows **access** to hard-to-reach locations: long water crossing, road/railway crossing, and mountainous terrain
- Increased inspection **efficiency**: better point of views, complete and rigorous assessment of the line

5. Future Applications in Robotics (I)

Roadmap for the future development and implementation of robotic technologies for OHL

- Setting a *Vision*
- Understanding the *Drivers*
- Defining *Future States* to meet that *Vision*
- Listing the *Gaps* to achieve those *Future States*



5. Future Applications in Robotics (II)

- Examples of Future Robotic Applications
  - Robotic technologies have the potential to revolutionize the way transmission systems are constructed and maintained
  - UAV to measure compression connector condition
  - UAV equipped with a corrosion sensor to assess the conductor condition
  - Utilization of UAVs to supplement/replace climbing inspections

5. Future Applications in Robotics (III)

- Examples of Future Robotic Applications
  - Autonomous UAV Inspections of OHTL
    - ✓ A UAV would fly along a transmission line on a pre-programmed route which could range from 10 to 100s of kilometers
    - ✓ The UAV would contain visual, infrared, ultraviolet, LIDAR and RFI sensing systems
    - ✓ The route for the UAV would be preprogrammed with the location of structures so that images could be automatically collected
    - ✓ Image processing would automatically identify conditions in each of the images of flag them for an operator to evaluate in more detail
    - ✓ The results would be automatically integrated in to an “inspection database” and work management system for visualization by all the utility stakeholders

5. Future Applications in Robotics (IV)

- Robotics will greatly enhance the operability, versatility and efficiency of the inspection methods
  - ✓ Providing access to hard-to-reach locations
- The key benefits that robotic technologies equipped with NDT sensors will eventually provide include :
  - ✓ Assessment of conductor condition on OHTL
  - ✓ Life extension of aging overhead lines
  - ✓ Contribute to maintaining system reliability and in making optimal maintenance decisions
- Make a rational diagnosis of conductor condition from the sensor measurements
  - ✓ Measurements taken at different locations along the line
  - ✓ Determine conductor condition anywhere along the line

6. Gaps in Knowledge and Challenges

- How users can translate the output of the measurements into useful and practical information ?
- Make a rational diagnosis of the conductor condition from
  - ✓ Damages observed by visual inspection
  - ✓ NDT sensor measurements
- Extrapolate over the whole line length the diagnosis of the conductor condition at one location
  - ✓ Taking into account the different environments (e.g. corrosive, industrial, urban, wind exposure, …, etc.)
- Predict the remaining lifetime of the conductor from its actual condition at different measurement locations
  - ✓ Model to predict the residual lifetime of conductor

7. Conclusion

- This presentation based on a Cigre WG tutorial for the state-of-the-art review of robotic technologies
- Line Suspended Robots are designed to serve as the extended eyes and arms of the transmission lineman and their basic design function is to perform visual inspections
- Development of UAV's is very active as more and more prototypes are being built and more players are expected to enter the market as service providers of technology users
- Ground Based Robots are designed to remotely capture and control energized conductors
- Other types of robots are very useful for less-conventional works on specific systems, such as tower/pole climbing and insulator inspection
- The future of robotic technologies applied to OHLs is very promising
- The key benefits that robotic technologies will provide include:
  - Life extension of aging overhead lines and make a rational diagnosis
  - Maintenance tasks on OHLs

For further details and discussion please email

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