Transmission Line Inspection Robot

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ABSTRACT:

The inspection of high-voltage transmission lines is a dangerous and time-consuming job, that relies on especially trained workers operating tens of meters above the ground, and close to live lines with thousands of volts. The robot was designed with mobility in mind, so that cable spacers, suspension clamps and other obstacles, which so far have prevented the use of robots for inspection of high-voltage lines, would not hamper the operation of the machine. After careful considerations on mobility, the robot was designed, and a prototype was built. Results of tests, performed on facilities reproducing real field conditions.

Keyword's – Inspection, Controlling, Autonomous, counter weight.

I . INTRODUCTION

The high-voltage transmission lines connecting electric energy production facilities to large urban centers are vital elements of electrical infrastructure. Any failure in such lines may bring severe consequences to people's daily lives, affecting transportation, health, security and sanitation, to mention just a few. Therefore, the proper maintenance of high-voltage transmission lines is of extreme importance. Preventive maintenance of the lines aims at detecting damages in the case or in the core of the cables, and requires people to walk on the lines – a time-consuming and dangerous job, in spite of all the safety procedures applied.

In addition, when the lines are being inspected, the transmission of electricity must be temporarily suspended, which means that other lines may be overcharged in order to compensate for the line that is undergoing maintenance. It is essential that preventive maintenance of high-voltage transmission lines be carried out in a safer and more efficient way, ideally without requiring the interruption of the electric energy supply. However, previous attempts to automate this task have been hampered by the spacers, suspension clamps and other devices installed on the lines, which represent formidable obstacles that need to be overcome tens of meters above the ground. High mobility is required in order to negotiate such obstacles. A robot designed for wireless inspection of powered high-voltage transmission lines. The basic concept of Robot will be introduced, as well as its mechanical design and control system.

II. INSPECTION OF TRANSMISSION LINE

High-voltage transmission lines are usually arranged in bundles of 2, 4 or more wires, supported by transmission towers. The distance between the towers is usually between 300m and 500m, and they may be located inside forests, on mountains and in other isolated places.

The suspended transmission lines are often composed of a metallic core and metallic casing. When exposed to the elements, the lines may suffer from corrosion, damages by lightning bolts, or even rupture of the core. In order to inspect the lines, workers must walk on the lines, in many cases suspended 100m above the ground. Special gondolas may also be employed, allowing the operator to "slide" on the cables.

These methods imply the interruption of transmission of electricity, require skilled workers, and expose the workers to unnecessary levels of danger and stress. One option to this method is to carry out visual inspection of the cables by helicopter with video cameras. Pattern-recognition algorithms may be used to improve the efficiency of inspection by video.

However, these inspection tasks tend to be expensive, and often provide just partial images of the cables. Flying helicopters close to the transmission lines and towers also involves risks that should be avoided. Some of these risks may be reduced by employing unmanned helicopters. Visual inspection from the ground is sometimes performed, but with very limited results.

As alternatives to visual inspection, thermal sensing, X-ray and electric sensing can be used to detect damages in the transmission lines, but the sensors need to be positioned very close to the cables.

In the span between the towers, spacers are placed to keep the distance between the cables and avoid them from touching each other when the wind blows. Spacers may come in different shapes, and their bolts also need to be inspected from time to time(Fig.2(a)). In addition, the transmission lines are supported from the top by vertical structures consisting of insulators, connected to the towers. Suspension clamps are used to connect the lines to the insulators(Fig.2(b)). The maintenance of these structures is easier because they are located on the towers, but a detailed inspection would still require the interruption of electricity transmission.



Figure1: Worker performing maintenance on transmission lines

III. WIND EFFECT

During the study of the wind effect on the robot, two hypotheses were considered: the robot was modeled as a simple pendulum or as two opposing pendulums. The results pointed here are qualitative, but lead to conclusions about the influence of the shape and configuration in the reduction of the amplitude of oscillation and in the improvement of the stability of the system.

IV. MECHANICAL MODEL

1. Motion Unit

The motion unit consists of two shafts, each with two pulleys. A DC motor is embedded in one of the pulley shafts. The torque is then transmitted to the other pulley shaft by a timing belt. The inner structure of the motion unit is composed of aluminum plates that form a cell. The structure is lightweight, has enough structural strength, and is relatively simple to build. The pulleys are made of aluminum plates bent to the desired shape by pressing, and coated with conductive rubber.

If normal rubber were used, it would function as a layer of insulation, resulting in the formation or electric arcs between the lines and the metallic body of the robot. To avoid this problem, the entire robot is kept at the same voltage of the transmission lines. Each vertical pole is made of an aluminum pipe, connected to the motion unit by a passive revolution joints (P1 or P2 in Fig. 5), and to the base of the robot by an active revolution joint (M3 or M5 in Fig. 5).

The vertical pole can be easily connected or disconnected to the motion unit by a pin, and to the base by a locking mechanism.

2. Base

The base of the robot houses the actuators of the vertical poles, as well as of the first link of the counter-weight manipulator (see Fig. 6). To drive each vertical pole, a geared DC motor of 150W is connected to a Harmonic-Drive transmission, providing a maximum continuous torque of 216Nm. High torque may be necessary especially when performing the Acrobatic Modes 1 and 2 on inclined cables, when the entire robot is supported by only one motion unit.

2. Manipulator and counter-weight

The counter-weight must be placed as far as possible from the base of the manipulator in order to maximize its influence over the position of the center of mass of the robot. this requires the actuators of the manipulator to be powerful and relatively heavy if compared to the other components of the robot.

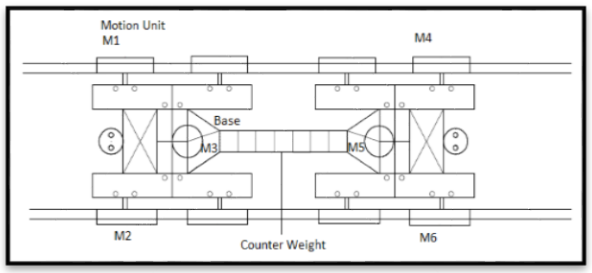


Figure 2: Configuration with two locomotion system

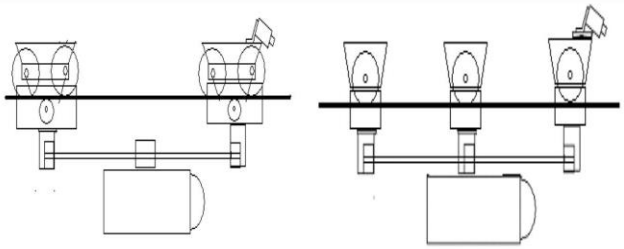


Figure 3: Configuration with three locomotion system.

V. AUTOMATION

1. Basic Concept

Initially, snake-like robots, or robots that move like inch-worms were considered for this application, but it soon became clear that they would be too complex and slow. In addition, transmission lines are unstructured environments, where robots would be exposed to changes in weather and obstacles in several different configurations. A more robust approach had to be sought. For this purpose, mobility by controlling the center of mass of the robot was proposed. This concept had already been employed in different robots based on crawlers for moving loads on slopes.
However, for inspection of transmission lines, the robot would need at least two supporting points and one counter-weight. By moving the counter-weight, it is possible to change the position of the center of mass, and thus lift one of the supporting points. Therefore, when one of the shafts is climbing an obstacle (and momentarily losing traction), the other shaft is still in contact with the cable and is able to drive the robot forward. This feature is especially useful when one of the motion units is lifted for overcoming large obstacles. As for the shape of the motion units, several configurations have been simulated with ADAMS®.

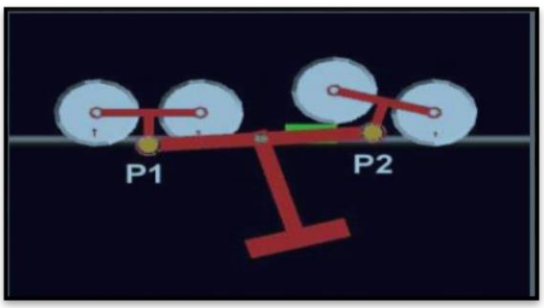


Figure 4 Simulation of the Motion unit

The two shafts are in the upper part of the motion unit, and the connection point with the vertical pole (a passive rotation joint, P1 or P2) is in a lower position, between the shafts. The

acrobatic modes introduced before have also been simulated. The necessary mass in the counter-weight to lift the robot in different configurations was confirmed, as well as unstable positions in which the robot would fall from the lines. The simulations provided valuable data that were used when testing the prototype and calibrating the positions of the counter-weight for the performance of the acrobatic modes.

VI. HARDWARE DESIGN SPECIFICATION

1. Pic Microcontroller

A microcontroller contains one or more CPUs (Processor Core) along with memory and Programmable input /output peripherals. Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as small amount Of RAM.

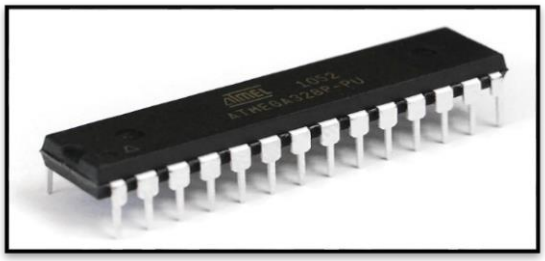


Figure 5 Pic Microcontroller

2. Bluetooth

HC serial Bluetooth products consist of Bluetooth serial interface module and Bluetooth adapter, such as:

(1) Bluetooth serial interface module:

Industrial level: HC-03, HC-04(HC-04-M, HC-04-S)

Civil level: HC-05, HC-06(HC-06-M, HC-06-S) ,(HC-05-D, HC-06-D)

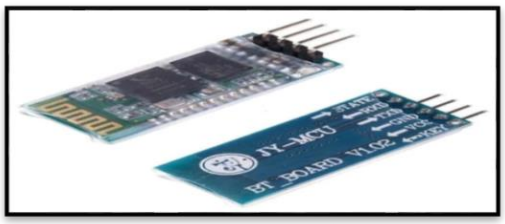


Figure 6 Bluetooth Module

(2) Bluetooth adapter: HC-M4, HC-M6

This document mainly introduces Bluetooth serial module. Bluetooth serial module is used for converting serial port to Bluetooth. These modules have two modes: master and slaver device. The device named after even number is defined to be master or slaver when out of factory and can't be changed to the other mode. But for the device named after odd number, users can set the work mode (master or slaver) of the device by AT commands.
Master device: HC-04-M, M=master
Slave device: HC-04-S, S=slaver

3. Relay

A relay is an electrical switch that uses an electromagnet to move the switch from the off to on position instead of a person moving the switch. It takes a relatively small amount of power to turn on a relay but the relay can control something that draws much more power. Ex: A relay is used to control the air conditioner in your home. The AC unit probably runs off of 220VAC at around 30A. That's 6600 Watts! The coil that controls the relay may only need a few watts to pull the contacts together.



Figure 7 Relay

4. Jonhson Motor

A Johnson motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.



Figure 8 Johnson Motor (10 A)

5. Camera

A camera is an optical instrument for recording or capturing images, which may be stored locally, transmitted to another location, or both. The images may be individual still photographs or sequences of images constituting videos or movies. The camera is a remote sensing device as it senses subjects without any contact. The word camera comes from camera obscure, which means "dark chamber" and is the Latin name of the original device for projecting an image of external reality onto a flat surface. The modern photographic camera evolved from the camera obscure. The functioning of the camera is very similar to the functioning of the human eye.



Figure 9 Camera and TV Tuner

VII. ROBOT – CONTROL SYSTEM

Robot can be controlled in semi-automatic mode, which means the user is always in charge of the operation, but does not need to control every single detail. In other words, when Robot is performing the Acrobatic modes, the user simply authorizes the execution of the steps, but does not need to drive the manipulator and vertical poles to the correct, predefined positions.

Those positions are stored in the memory of the controller. A higher degree of autonomy can be achieved when the robot is simply moving over the transmission lines acquiring data for preventive maintenance. However, complete autonomous control for the entire process is unrealistic in the current stage, due to the unstructured environment and the variety of spacers and obstacles that need to be crossed.

1. Portable Control Unit

The portable control unit was implemented with a tablet notebook, a panel with switches, antennas for wireless communication, batteries and the associated circuitry, assembled inside a robust and compact case. The entire assembly is dust-proof and splash-proof and has been extensively tested in outdoor environments. The notebook may display the current configuration of Robot with data from its encoders and provides additional information to help the user control the robot, such as images from cameras.

2. Wireless Communication

Implementing a reliable, long-distance wireless communication system can be very tricky due to the restrictions in power usage and the limited angular range of the antennas. With the system described above, it was possible to establish stable wireless communication over 200m away from the robot, provided the robot is in clear view from the control unit.

VIII. CONCLUSION

Robot is under development as a robot for remote inspection of high-voltage lines. By controlling the position of its center of mass, it presents enough mobility to overcome the obstacles that often prevent other machines from moving on transmission lines. Even though there are several features that need to be improved prior to its deployment in real transmission lines, the results of experiments so far suggest that a version for real operation may be ready in the near future.

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