A Novel Robotic Mechanism for Efficient Inspection of High-Voltage Transmission Lines

Oswaldo Ramos Neto, José Mário Nishihara, Davi Riiti Goto do Valle, Alexandre Domingues,
Ronnier Frates Rohrich and André Schneider de Oliveira
e-mail: {oswaldo | josalb | daviriit | alexandredomingues}@alunos.utfpr.edu.br
{rohrich | andreoliveira}@utfpr.edu.br

***Abstract*—High-voltage transmission line inspections have traditionally been performed using helicopters and human operators, making it a hazardous and costly task. This paper presents a novel robotic system designed to autonomously navigate transmission lines and overcome obstacles such as vibration dampers. The proposed system incorporates a movement mechanism that utilizes stepper motors and a gear-driven pivoting system, allowing the robot to navigate obstacles efficiently while maintaining stability. The structure, developed using aluminum profiles for modularity, ensures adaptability for future enhancements. Experimental results demonstrate the effectiveness of the design in maintaining safe and continuous movement along power lines, offering a promising alternative for autonomous power line inspection.**

Keywords-Inspection; Robots; Power cables; Safety; Power system reliability; Wheels.

I. INTRODUCTION

High-voltage power line inspection is traditionally performed by helicopters and human operators, with significant safety concerns. This issue has led to the development of autonomous robotic solutions that can perform inspections, improving safety and efficiency. However, the main difficulty is designing a system capable of overcoming the environmental and structural obstacles inherent in power lines.

The challenge is ensuring that robotic systems can navigate these obstacles while maintaining balance and operational efficiency. This paper discusses a novel mechanism capable of autonomous, safe, and reliable power line inspections, which overcomes the elements of the power line.

The rest of the paper is structured as follows. Section II provides a review of the related literature. Section III introduces the design and development of the autonomous cable-line crawling robot. Section IV details the mechanism proposed for overcoming obstacles on power line components. Finally, Section V presents the conclusions, including key findings and recommendations for future research.

II. RELATED WORK

Some strategies have been developed to assist inspection robots in overcoming obstacles on power transmission lines. One interesting approach involves employing a sophisticated movement strategy wherein the robot secures itself at a stable point and maneuvers its support and movement segments over an obstacle, as discussed in [1]. This method, however, can be complex to implement and may require precise coordination, posing a challenge in highly variable environmental conditions.

Another approach focuses on designing robots that can actively adjust their center of mass, inspired by how monkeys navigate branches, as in [2]. This approach has shown effectiveness in obstacle avoidance by allowing the robot's structure to shift dynamically. Despite its promise, constant rebalancing during operation presents a challenge, particularly under conditions of instability like gusty winds.

Research efforts have also concentrated on enhancing robot stability during transit across the line's components [3]. These methods ensure the robot maintains balance while moving, although they may limit the system's agility and responsiveness. These limitations emphasize the need for solutions that balance stability, agility, and environmental adaptability.

This paper addresses these gaps by proposing a mechanism that combines the overcoming of power line elements (such as dampers, wire markers, and insulators) with stability, aiming to improve the efficiency and safety of autonomous line inspections, same in adverse weather conditions.

III. THE ROBOTIC MECHANISM

In this type of robot, the center of gravity is crucial: the lower it is positioned, the greater the stability. Based on this principle, the structure was designed using SOLIDWORKS mechanical modeling and analysis software to achieve optimal mass distribution. The objective was to ensure that the center of gravity was centrally located and positioned below the support point, as presented in Figure 1.

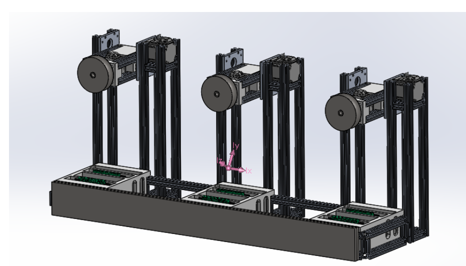

Figure 1. Robotic Mechanism for Inspection of High-Voltage Transmission Lines.

The structure was built using aluminum profiles, allowing for easy assembly and the potential for adding new modules. Steel plates were also used to cover the front of the robot, which not only protect the control systems from external elements but also serve as counterweights. The structure can

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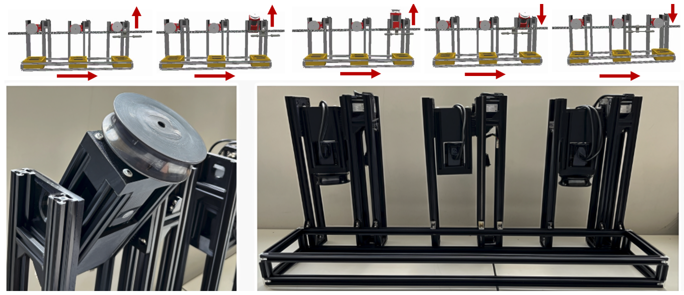

Figure 2. Demonstration of actuation and obstacle avoidance.

be divided into four parts: the main section, which houses the 24-volt batteries and controllers, and three vertical structures that accommodate the motors and actuators, as depicted in Figure 3.

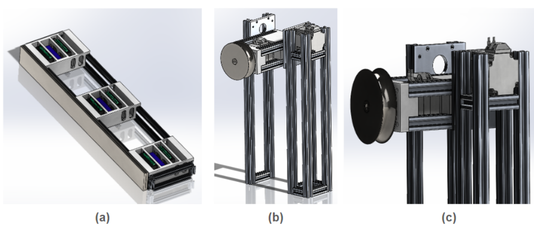

Figure 3. Robot elements.

IV. Actuation and Obstacle Avoidance

A mechanism was developed that uses three stepper motors, each equipped with a steel pulley with a one-inch gap to allow the robot to move along the transmission cables. As the pulleys rotate, they provide linear motion along the steel cable, ensuring stable and precise movement, as seen in Figure 2.

A pivoting mechanism was designed for the movement system to enable the robot to overcome obstacles fixed to the transmission line. This mechanism employs three stepper motors, one for each pulley—mounted on the sides of the supports. Through a gear transmission system with a 2.75:1 reduction ratio, each pulley support is sequentially rotated clockwise until it reaches a 90 degree angle, as shown in Figure 4, effectively moving the pulleys away from the obstacle. Once the obstacle is cleared, the pulleys are returned counterclockwise to their original position on the transmission line.

Additionally, a locking system was implemented using solenoid actuators. When the pulley support system is correctly positioned, these actuators engage to prevent excessive load on the movement system, thereby protecting the motors from overload. This mechanism serves as a mechanical safety lock ensuring that the robot remains securely suspended on the transmission cables.

V. Conclusion

This paper presents a novel cable-line crawling robot to overcome the obstacles commonly found on power lines.

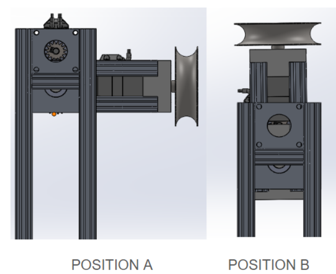

Figure 4. Pulley Positions.

The proposed solution successfully navigates power lines and bypasses obstacles such as dampers, wire markers, and insulators, maintaining stability to perform integrity inspections. The modular design of the inspection robot, using aluminum profiles, allows it to be adapted to various power line configurations by adjusting its length and incorporating additional robotic arms.

Future research will focus on improve control systems, integrating advanced sensors like LIDAR, and enhancing autonomous decision-making capabilities. Optimization of energy efficiency and mobility will also be a priority. These improvements aim to create a fully autonomous and reliable inspection robot for power line maintenance.

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