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Optimization of Lockout/Tagout (LOTO) Procedures Using Connected Padlocks

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ABSTRACT

Lockout/Tagout (LOTO) procedures are essential for ensuring worker safety during maintenance and repair of industrial facilities. Traditional LOTO processes, however, can be time-consuming and inefficient, especially in large industrial sites where multiple lockout points are spread across large areas. This research study focuses on optimizing the LOTO process through the implementation of connected padlocks. The objective is to evaluate the feasibility of smart padlocks in industrial environments and quantify potential time savings compared to conventional LOTO procedures.

To achieve this, the study follows a structured methodology. The first phase involves benchmarking existing connected padlocks based on criteria such as communication technology, multi-user access management, security, power consumption, and cost-effectiveness. This analysis highlights limitations in currently available smart padlocks, including their inability to handle multiple codes per lockout action and inadequate connectivity for industrial applications. Given these constraints, the second phase explores the development of a customized padlock solution tailored to industrial LOTO requirements.

In a next step, this study explores various communication technologies, comparing their reliability, scalability, and suitability for industrial applications. The analysis considers factors such as network coverage, security, and energy consumption to determine the most viable option for real-world LOTO applications.

The final phase of the research study involves the experimental validation of the proposed system. A series of tests are conducted to assess communication reliability in factory settings, particularly the ability to penetrate obstacles and maintain bidirectional messaging. Additionally, the study quantifies the potential reduction in LOTO execution time achieved by connected padlocks, with a focus on improving response time and operational efficiency.

Based on our analysis, LoRaWAN has been selected as the preferred communication method. LoRaWAN operates on sub-GHz ISM bands, specifically 915 MHz in North America. It provides bandwidth options of 125 kHz with data rates ranging from 0.3 kbps to 50 kbps. This technology is particularly suited for industrial environments as it ensures long-range communication and strong obstacle penetration, making it ideal for large-scale lockout procedures.

By optimizing geographic LOTO procedures through connected padlocks, this research aims to enhance both safety and productivity. The contributions include a comprehensive evaluation of smart padlocks, an analysis of the most suitable communication technology, and insights into potential industrial adoption. The findings from this study serve as a foundation for future research into Artificial Intelligence-driven lockout management and Internet-of-Things-based predictive maintenance, further improving industrial safety protocols and reducing downtime in critical operations.