International Journal of Information System Modeling and Design
Volume 17 • Issue 1 • January-December 2026

Development of a Low-Power Consumption Monitoring System for Tension Stringing Construction

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Received: April 20th, 2025 | **Accepted:** February 3rd, 2026

ABSTRACT

In transmission line overhead construction, the poor durability of monitoring systems creates a problem for practical engineering implementation. This study established a mathematical model for data transmission patterns in monitoring systems through collected operational data, which calculates the optimal rotation frequency for information delivery by analyzing the proportional relationship between buffer queue length and actual input throughput within the monitoring dataset. The study also proposed an M/M/1/N/∞ queuing model, which is applicable to the data transmission of the monitoring system in transmission line overhead construction. The monitoring system was successfully applied in a 220kV line project in Guangdong Province with a total power consumption of 65% during three days of monitoring. The duration was improved by 2.5 times in comparison with the traditional monitoring system, which was greater than the construction period of a single tension-resistant section of the overhead line.

KEYWORDS

Transmission Line Overhead Construction, Monitoring System, M/M/1/N/∞ Queuing Model, Idle Time of Data Transmission, Dormant State

INTRODUCTION

With the continuous promotion of digitalization in the power industry, digital twin technology has gradually been applied in the process of overhead line construction. In the construction of overhead transmission line, some key engineering data cannot be easily obtained, and online monitoring equipment is needed to collect and transmit the data (Yan & Lee, 2022). However, once monitoring equipment is installed on ropes and metal fixtures used in high-altitude construction, it is difficult to disassemble and charge it during the construction process. Moreover, the construction site is usually

DOI: 10.4018/IJISMD.401377

in the wild, maintaining a stable power supply is a challenge, and the construction time for a tension section usually lasts for two to three days. Consequently, the operational longevity of surveillance devices now stands as the primary constraint hindering technological advancement in aerial power line monitoring systems, particularly within power transmission infrastructure maintenance scenarios.

Transmission line overhead construction data cannot be easily accessed, and online monitoring equipment is needed to collect and transmit the data. Moreover, the construction site is typically situated in a field where there is no reliable power supply, and the installation of a tensile section typically takes about two to three days. Moreover, considering the safety of the overhead line construction, the monitoring equipment is generally small and lightweight. Once installed, monitoring equipment located on construction ropes and fixtures high in the air is difficult to remove and recharge. As a result, the range has become a key constraint to the development of the field of overhead line construction monitoring.

Overhead line construction sites are often located in remote areas, where the power lines are hard to connect and susceptible to damage, and the monitoring systems typically rely on battery power (Zhu et al., 2018). Because the battery pack of the monitoring system is embedded in the ropes and accessories of overhead line construction, excessive battery size can cause limited storage capacity, which makes the monitoring system unable last for the entire construction period required for a single tension-resistant section of the overhead line. Existing transmission line construction force measurement and control instrument endurance time is only about eight hours, so the construction process power supply needs to be repeatedly disassembled, seriously reducing the efficiency of overhead line construction. In order to extend the lifespan of the system, Sah et al. (2023) proposed a method of adding solar panels to continuously supplement the system's electrical energy. However, they are prone to damage during actual construction and installation, and the power supply effect is easily affected by the environment. Inductive power harvesting for energy collection has also been applied in transmission line monitoring equipment (Huang et al., 2023). However, this method necessitates a primary current around the equipment area and is not suitable for monitoring overhead line construction. As a result, enhancing the endurance of the overhead construction monitoring system solely through hardware design is challenging.

Existing studies have shown that most of the energy consumed by monitoring systems is in data transmission (Lu & Zhan, 2022; Wang et al., 2016). To lower the energy usage of the monitoring system during data transmission, low-power data transmission methods such as Media Access Control protocol (Chen et al., 2022) and Source Media Access Control protocol (Rao et al, 2015) have emerged. The basic idea of these approaches is to turn sensors that are in the idle period of data transmission into a low-power hibernation state (Zhou et al., 2014). However, the idea is limited to applications in monitoring systems with only a single sensor, like outdoor temperature monitoring. In the case of multi-monitoring point systems such as overhead line construction, the complex data transmission idle time between multiple sensors is so difficult to set that it is not clear when the sensors switch to a low-power dormant state. Thus, for an overhead line construction monitoring system that employs a low-power hibernation strategy, it is essential to first identify precisely the idle time for data transmission of each sensor in the system.

Considering that the process in which data from each sensor in the monitoring system reaches the terminal via channel transmission resembles the way customers queue to purchase tickets, queuing theory (Sharma et al., 2020) has been widely used in studies related to data transmission in complex networks (Song et al., 2023). Feng and Liang (2023) applied queuing theory to tactical communications idle time. This offers a basis for determining the data transmission idle time for each sensor in the overhead construction monitoring system. In this study, a queuing model was proposed for data transmission of overhead line construction monitoring system. This model was based on the concept of placing sensors in a dormant state during idle periods. The aim was to determine the idle time for data transmission and implement a low-power mode by turning sensors into a dormant state during idle periods, thereby achieving a low-power consumption design for the monitoring system.

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