Temperature and Humidity Control System for a Munitions Warehouse: Integrating IoT, Machine Learning, and Independent Control

Abstract

Maintaining stable temperature and humidity in ammunition storage facilities is essential to ensure safety and reliability. Environmental fluctuations can degrade explosive materials, shorten their lifespan, and increase the risk of fire or accidental detonation. Conventional manual monitoring methods are often inefficient and lack predictive capabilities, creating the need for a smarter and more reliable solution. This study presents the design of an integrated system that combines Internet of Things (IoT), Machine Learning (ML), and autonomous automatic control to regulate environmental conditions in ammunition depots. The system employs BME680 and DHT11 sensors to measure temperature, humidity, and air quality in real-time. Data are processed by microcontrollers such as ESP32 or STM32 and analysed using a linear regression model, enabling accurate predictions of future environmental changes. To ensure resilience, a backup NodeMCU-based controller is included, which maintains actuator functionality (fans, humidifiers, and ventilation systems) even in the event of internet or server failures. A sensor clustering method is also applied to optimise sensor deployment, reducing costs without sacrificing accuracy. Experimental results demonstrate that the system provides accurate real-time monitoring, predictive insights with less than 10% error, and reliable autonomous control. Compared to conventional approaches, the integration of IoT, ML, and fallback control improves safety, reduces operational costs, and ensures continuous functionality under adverse conditions. This research highlights the effectiveness of combining IoT and ML for ammunition warehouse management and indicates potential applications in other industries requiring strict environmental control, such as pharmaceuticals, logistics, and food storage.