

**The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)  
October 14-16, 2025, Chiayi, Taiwan**

## **SIGNAL CHARACTERIZATION FOR ACTUATOR OPERATION STATUS MONITORING IN SMART VERTICAL FARMS**

**Ezatullah Zakir<sup>1</sup>, Emmanuel Bicamumakuba<sup>1</sup>, Md Nasim Reza<sup>1,2</sup>, Kyu-Ho Lee<sup>1,2</sup>, Su Young Lee<sup>1</sup>, Jin Sook Kim<sup>1</sup>, Sun-Ok Chung<sup>1,2\*</sup>**

<sup>1</sup> Department of Agricultural Machinery Engineering, Graduate School, Chungnam National University, Daejeon 34134, Republic of Korea. <sup>2</sup> Department of Smart Agricultural Systems, Graduate School, Chungnam National University, Daejeon 34134, Republic of Korea.

\*Corresponding Author: sochung@cnu.ac.kr

### **ABSTRACT**

Vertical farming presents a sustainable solution for high-yield crop production in space-constrained environments by enabling precise control over environmental parameters. However, effective implementation depends not only on environmental monitoring but also on the reliable operation of actuators that regulate system condition. The objective of this study was to characterize power consumption signals from actuators within smart vertical farms to facilitate precise monitoring, assessment of operational status, and proactive detection of potential anomalies. A multi-layer sensor network was fabricated and installed to collect a real-time data on actuator operational status using a commercial current sensor, integrated with microcontrollers. These microcontrollers were also interfaced with environmental sensors to coordinate actuator control and data acquisition. Advanced preprocessing techniques, such as digital filtering and signal smoothing algorithms, were applied to raw signals to reduce noise and highlight significant operational features. Analysis of power consumption signals provided detailed insights into the operational dynamics of each actuator. By correlating specific power consumption patterns with corresponding actuator status and transition phases, the signal-based methodology effectively differentiated normal operational behaviors from potential irregularities. Results validated the accuracy and reliability of power-based signal characterization, demonstrating the potential as an efficient, scalable approach for real-time operational monitoring and anomaly detection of vertical farming components. This approach supports the development of anomaly detection and lays the groundwork for predictive maintenance strategies. Future research will focus on integrating machine learning algorithms for automated classification of actuator states and anomaly detection, contributing to more resilient and energy-efficient vertical farming systems

**Keywords:** Smart farming, IoT, environmental control, power consumption, signal characterization.

### **INTRODUCTION**

Vertical farming has emerged as a promising solution to urban food security challenges by enabling high-yield production within limited spaces. The operation of vertical farms primarily

depends on actuators that regulate environmental conditions. While previous studies have primarily emphasized monitoring environmental parameters, relatively little attention has been directed toward actuator reliability. Ensuring proper actuator function is essential for sustaining crop growth, optimizing energy efficiency, and maintaining overall system performance (Iqbal et al., 2019). This study aimed to characterize actuator power consumption signals to assess performance, detect anomalies, and support predictive maintenance strategies.

## **MATERIALS AND METHODS**

The experimental setup comprised three vertical cultivation layers, each equipped with two air-circulating fans, two pumps for nutrient and water supply, LED grow lights in each layer, and a solenoid valve assigned to each pump. Power consumption was monitored using commercial Hall-effect current sensors interfaced with microcontrollers. The sensor output voltage was sampled at 1000 Hz to accurately capture transient events and converted into 16-bit root mean square (RMS) power values. These data were time-stamped, address-labeled, and transmitted at 10 Hz through a LoRa module to the central control unit. The received signals were processed using a digital low-pass filter and a moving average algorithm to reduce noise. The filtered signals were then characterized by analyzing start-up transients, steady-state levels, and irregular fluctuations to determine normal from abnormal operation.

## **RESULTS AND DISCUSSION**

Power signal analysis revealed distinct operational patterns of actuators. Fans maintained RMS currents of 0.37–0.42 A, with start-up transients peaking at 0.75 A before stabilizing within 2–3 s. Pumps showed ON/OFF cycles between 0.02 and 0.61 A, reflecting load-dependent operation. Filtering highlighted transient fluctuations and abnormal responses, demonstrating that power signals can effectively characterize actuator behavior and enable early anomaly detection.

## **CONCLUSIONS**

Power consumption signals effectively reflect actuator operations in smart vertical farms, and preprocessing enables differentiation between normal and abnormal patterns, supporting real-time monitoring and predictive maintenance.

## **ACKNOWLEDGEMENTS**

This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET), through K-Vertical Farm Globalization Project, funded by the Ministry of Agriculture, Food and Rural Affairs (MAFRA) (Project No. RS-2025-02303373), Republic of Korea.

## **REFERENCES**

Iqbal, Z., N. Islam, B.E. Jang, M. Ali, S.N. Kabir, D.H. Lee, K.D. Na, S.B. Park, and S.O. Chung. 2019. Monitoring the operating status of an automatic harmful fly collector for smart greenhouses. *Journal of Biosystems Engineering* 4: 258-68.