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POWER CONSUMPTION SIGNAL CHARACTERIZATION OF BLDC-BASED AGRICULTURAL FANS FOR MALFUNCTION DETECTION FOR SMART GREENHOUSES

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Abstract

Effective management of environmental parameters, notably temperature and humidity, is critical for ensuring optimal plant growth and productivity in smart greenhouses. Brushless (BLDC) fans are commonly utilized for controlling greenhouse ventilation and humidity levels. The primary aim of this study was to characterize the power consumption of BLDC agricultural fans to identify operational anomalies and facilitate predictive maintenance strategies. An experimental setup was devised, involving controlled operational tests of a BLDC fan across various rotational speeds, reflective of practical greenhouse operation scenarios. Power consumption data was collected using a current sensor integrated with voltage-sensing circuits and interfaced with a microcontroller for precise data acquisition. Initial preprocessing employed a low-pass filter to mitigate signal noise, thereby enhancing the reliability of the recorded data. The processed signals underwent frequency domain transformation to allow detailed inspection and differentiation of normal and abnormal fan operational patterns. Analysis of the frequency domain signals revealed distinctive anomalies indicative of potential mechanical or electrical faults, including irregular power surges and unstable current fluctuations, and observed during fan startup phases. These anomalous patterns serve effectively as early indicators of mechanical degradation, electrical instability, or imminent component failures. The diagnostic features identified through power consumption characterization enhance early fault detection, enabling proactive maintenance measures. Integrating these indicators into predictive algorithms improves the reliability and operational longevity of greenhouse ventilation systems.

Keywords: Smart greenhouse, microprocessor, power monitoring, predictive maintenance, anomaly detection.

INTRODUCTION

Smart greenhouse management requires precise control of environmental status. Brushless DC fans are used for ventilation, but a malfunction reduces system efficiency. Monitoring power consumption signals offers a non-intrusive method for malfunction detection (Ghiasi et al.,

2023). The need for energy-efficient, reliable greenhouses drives diagnostics to sustain fan performance and lower costs (Zhi et al., 2015). The objective of this study was to characterize BLDC fan power consumption to detect anomalies and enable predictive maintenance.

MATERIALS AND METHODS

A BLDC agricultural fan was evaluated under varying rotational speeds to simulate greenhouse conditions. Power consumption was measured using current sensors interfaced with a commercial microcontroller. A low-pass filter minimized signal noise, and frequency-domain analysis was used to differentiate normal from abnormal operations.

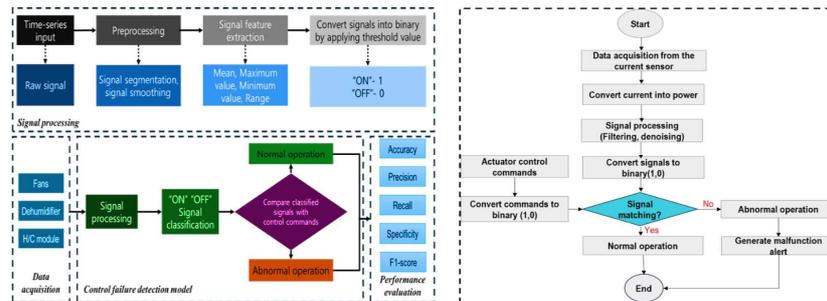


Fig. 1 Normal and abnormal power consumption detection workflow of BLDC fans.

RESULTS AND DISCUSSION

Frequency analysis showed malfunctions such as unstable current fluctuations, with startup spikes approximately 25% above steady state and power increases of 18% at medium speed and 42% at high speed. These patterns suggest potential malfunctions, confirming power signatures as effective early diagnostic features.

CONCLUSIONS

Characterizing BLDC fan power consumption provides an effective means of malfunction detection and predictive maintenance, offering a practical and cost-efficient approach to enhance the reliability and service life of greenhouse ventilation systems.

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