Intelligent Fault Diagnosis of Centrifugal Pumps Valves in Microbreweries

ECSA-11 2024 Conference

Marcio Rafael Buzoli, Matheus Luis Despirito, Fabio Romano Lofrano Dotto, Pedro de Oliveira Conceição Junior, Andre Luis Dias.

São Carlos School of Engineering (EESC) - University of São Paulo (USP) - São Carlos/SP - Brazil

Federal Institute of São Paulo (IFSP) - Sertãozinho/SP - Brazil

INSTITUTO FEDERAL São Paulo Campus Sertãozinho

USP

EESC · USP

Introduction

The brewing industry has seen significant growth, particularly in the microbrewery sector, where small-scale production demands cost-effective and reliable solutions. Centrifugal pumps, integral to these operations, facilitate wort movement through brewing stages. However, pump malfunctions, including valve blockages, can disrupt production and impact product quality. Intelligent Fault Detection (IFD) systems have gained attention for condition monitoring in complex environments, supporting proactive maintenance while minimizing costs. This study explores IFD application for centrifugal pumps, focusing on an accessible, sensor-less approach using pump drive data to enhance reliability and efficiency in microbrewery operations.

Background

Machine fault diagnosis has evolved significantly with machine learning (ML) applications, where algorithms like Support Vector Machine (SVM) and Artificial Neural Networks (ANNs) are now integral for identifying machine health states[1]. Traditionally, fault detection required extensive human involvement, but modern ML models autonomously recognize faults, reducing operational downtime and improving efficiency. For rotating machinery, including pumps, previous studies have demonstrated the efficacy of SVM classifiers using PROFIdrive data in identifying fault conditions under various operating parameters[2]. This approach aligns with Industry 4.0 objectives by minimizing additional sensor needs and leveraging existing network data, thus providing a scalable solution for small-scale brewing facilities.

Proposed Method

The study's pilot setup was developed at the Federal Institute of São Paulo's microbrewery lab, where a centrifugal pump was adapted for condition monitoring (**Figure 1**). Data on electric current, torque, and power factor were collected from the pump's drive system via PROFINET network, eliminating the need for additional sensors.

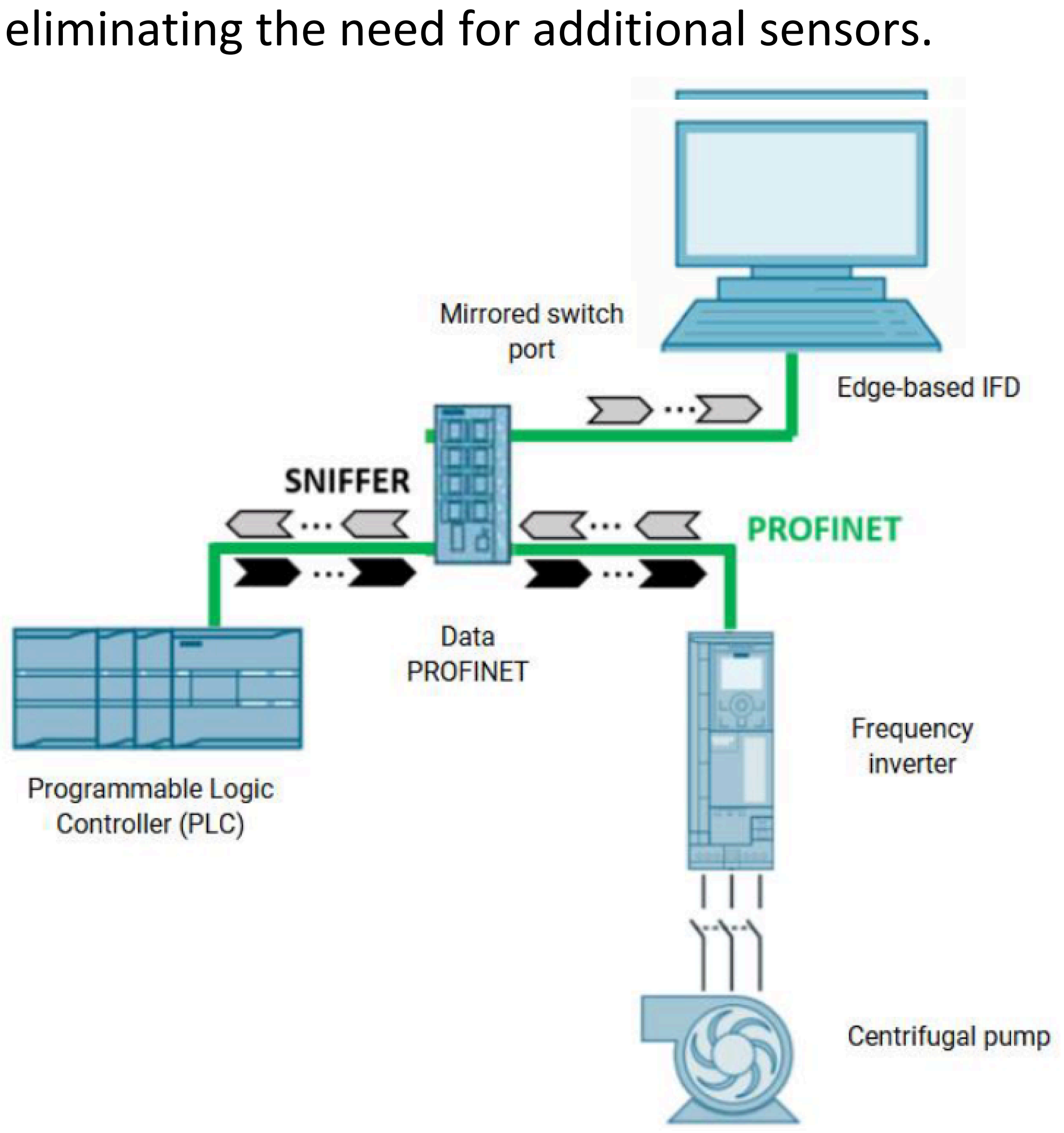

Figure 1: Control Panel of the Brewing Pilot Plant.

A managed switch with port mirroring was configured to capture data between the PLC and the frequency inverter. Fault conditions were simulated by blocking the pump's inlet and outlet valves, representing two distinct fault scenarios. Data was then collected and analyzed using Wireshark and a Python-based algorithm to create a comprehensive dataset for ML model training. Feature extraction included calculating attributes like mean, standard deviation, maximum value, minimum value, range (difference between maximum and minimum), skewness, kurtosis, entropy, and root mean square (RMS) to build a robust dataset for training.

Results and Discussion

The performance of Support Vector Machine (SVM) and Artificial Neural Network (ANN) models was evaluated based on accuracy, false positive rate (FPR), and false negative rate (FNR). Using all extracted features, the SVM model achieved an accuracy of 90.15%, with an FPR of 11.90% and an FNR of 8.40%. The ANN model, similarly trained, reached an accuracy of 89.66%, showing comparable effectiveness.

When focusing on individual features, power factor alone yielded the highest accuracy, with the ANN model achieving 90.64%. This suggests that power factor is a particularly strong indicator for fault detection, enabling effective monitoring even with fewer variables. The ANN model, therefore, demonstrated the best overall performance when focusing on this specific feature, highlighting its potential for efficient, targeted fault diagnosis.

These results suggest that both models are suitable for fault detection in centrifugal pumps, though the ANN model provides a slight edge in performance with the power factor. This supports the feasibility of using simpler, focused models to deliver cost-effective and reliable monitoring solutions for small-scale breweries.

Conclusion

This study demonstrates that both SVM and ANN models are effective for fault detection in centrifugal pumps within microbrewery settings, with the ANN model providing a slight edge in overall performance when focusing on the power factor as a primary indicator. The ANN model's accuracy of 90.64% with power factor alone suggests that targeted, resource-efficient monitoring solutions are feasible without sacrificing accuracy. These findings align with the demands of small-scale breweries for affordable, reliable diagnostic tools that leverage existing data sources. Future work may explore deep learning approaches and other simplified feature sets to further enhance fault detection efficiency and adaptability.

References

[1] Lei, Y.; Yang, B.; Jiang, X.; Jia, F.; Li, N.; Nandi, A. K. Applications of machine learning to machine fault diagnosis: A review 22 and roadmap. Mechanical Systems and Signal Processing 2020, 138, 106587. https://doi.org/10.1016/j.ymssp.2019.106587.

[2] Dias, A. L.; Turcato, A. C.; Sestito, G. S.; Rocha, M. S.; Brandão, D.; Nicoletti, R. A New Method for Fault Detection of Rotating 24 Machines in Motion Control Applications Using PROFIdrive Information and Support Vector Machine Classifier. J. Dyn. Sys., 25 Meas., Control 2021, 143(4), 041007. https://doi.org/10.1115/1.4048784..