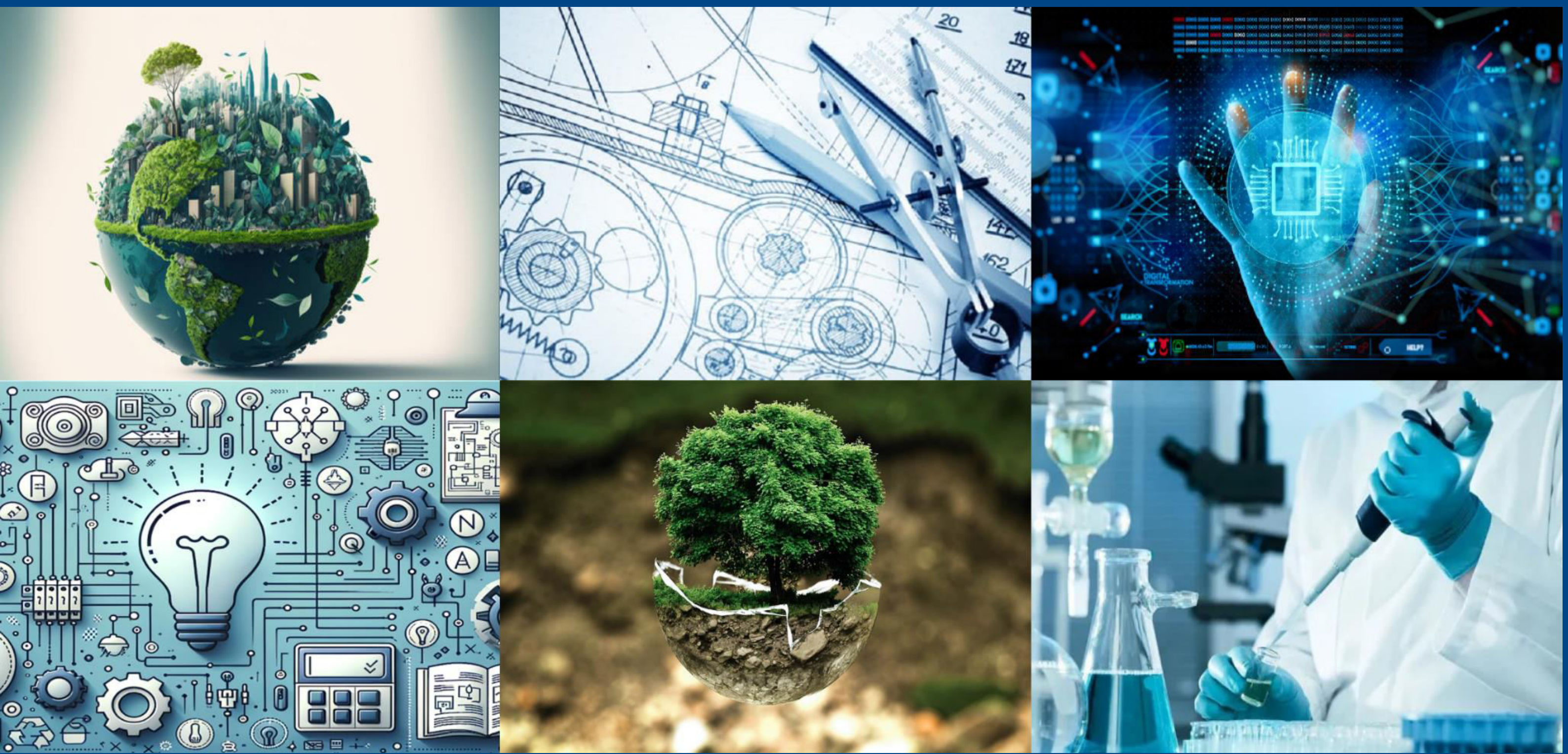
ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 8, Issue 4, April 2025

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Fault Detection in Refrigeration System using Machine Learning

Dinesh Shatrughna Ghodake[1], Onkar Santosh Shelar[2], Prajwal Satish Jagtap[3], Vishal Laxman Khandugol[4], Prof. Sandesh.B.Mane[5]

Diploma Student, Department of Mechanical Engineering, Jayawantrao Sawant Polytechnic, Pune, India

Lecturer, Department of Mechanical Engineering, Jayawantrao Sawant Polytechnic, Pune, India

ABSTRACT: Refrigeration systems play a crucial role in various industries, including food preservation, medical storage, and HVAC applications. Faults in these systems can lead to energy inefficiency, environmental damage, and high operational costs. Traditional fault detection methods are often time-consuming and prone to human error. To address these challenges, we developed a Machine Learning (ML)-based fault detection system utilizing temperature, humidity, and pressure sensors to quickly and accurately detect faults. A basic refrigeration model was constructed, incorporating three DHT22 sensors to detect Temperature And Humidity within the system. The proposed ML system enhances accuracy, minimizes downtime, and enables predictive maintenance, ultimately improving the reliability and energy efficiency of household refrigeration systems. Experimental results demonstrate that ML-based fault detection significantly outperforms traditional methods, making it a promising approach for smart and sustainable refrigeration technology. Various ML algorithms, including Decision Trees, Support Vector Machines (SVM), and Deep Learning models, were evaluated for their effectiveness in fault classification and prediction.

KEYWORDS: Machine Learning (ML), Temperature sensors, Humidity sensors, Pressure sensors ,DHT22 sensors.

I. INTRODUCTION

Refrigeration systems are essential across a range of applications, including food preservation, industrial processes, and environmental control, where maintaining low temperatures is critical for preventing spoilage and ensuring operational efficiency. Most conventional refrigeration systems operate on the vapour compression cycle, which includes four fundamental components: a compressor, a condenser, an expansion device, and an evaporator. In this cycle, the refrigerant is compressed to a high-pressure, high-temperature vapour, condensed into a liquid in the condenser by releasing heat, expanded through an expansion device to reduce pressure and temperature, and finally evaporated to absorb heat from the surroundings, thereby producing a cooling effect.

To improve the efficiency, monitoring, and diagnostic capabilities of refrigeration systems, this study presents the development of an enhanced refrigeration prototype incorporating modern sensing technologies and machine learning algorithms. The system integrates three DHT22 sensors positioned at critical locations to monitor temperature and humidity variations throughout the refrigeration cycle. Pressure gauges are installed at key points to measure refrigerant pressure in both vapour and liquid states, enabling early detection of anomalies such as leaks or blockages. A flow meter is placed between the evaporator and compressor to measure the refrigerant flow rate, ensuring effective system circulation. Additionally, an energy meter records power consumption, facilitating the calculation of the Coefficient of Performance (COP), a key indicator of energy efficiency. Data collected from these sensors is processed by an Arduino Uno microcontroller and displayed in real time through a digital interface. To enhance system intelligence, machine learning (ML) techniques are applied to the sensor data for fault detection and classification. The ML models are capable of identifying potential issues such as refrigerant leakage, pressure imbalances, compressor inefficiencies, and temperature anomalies. This approach enables predictive maintenance, reduces unexpected system failures, and optimizes energy usage by dynamically adjusting operational parameters based on real-time conditions.

The entire system is physically assembled on a durable frame constructed using mild steel rods and wooden plates, offering both stability and ease of access for testing and analysis. By integrating IoT-enabled sensors with machine learning algorithms, the proposed system demonstrates a scalable and intelligent solution for real-time performance

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

monitoring and fault diagnosis in refrigeration systems. This work aims to enhance energy efficiency, improve reliability, and promote sustainable practices in refrigeration technology.

II. FAULT DETECTION IN REFRIGERATION SYSTEM USING MACHINE LEARNING

Machine Learning (ML) has become a crucial tool for Fault Detection and Diagnosis (FDD) in refrigeration systems, addressing challenges related to system complexity, variability, and model uncertainties. Traditional model-based FDD methods often struggle due to the dynamic nature of refrigeration systems, making ML a more reliable and adaptable solution. One of the primary challenges in refrigeration system fault detection is its complexity and variability. Different system configurations and operating conditions make it difficult to develop a single fault detection model that works universally (Lo et al., 2019).

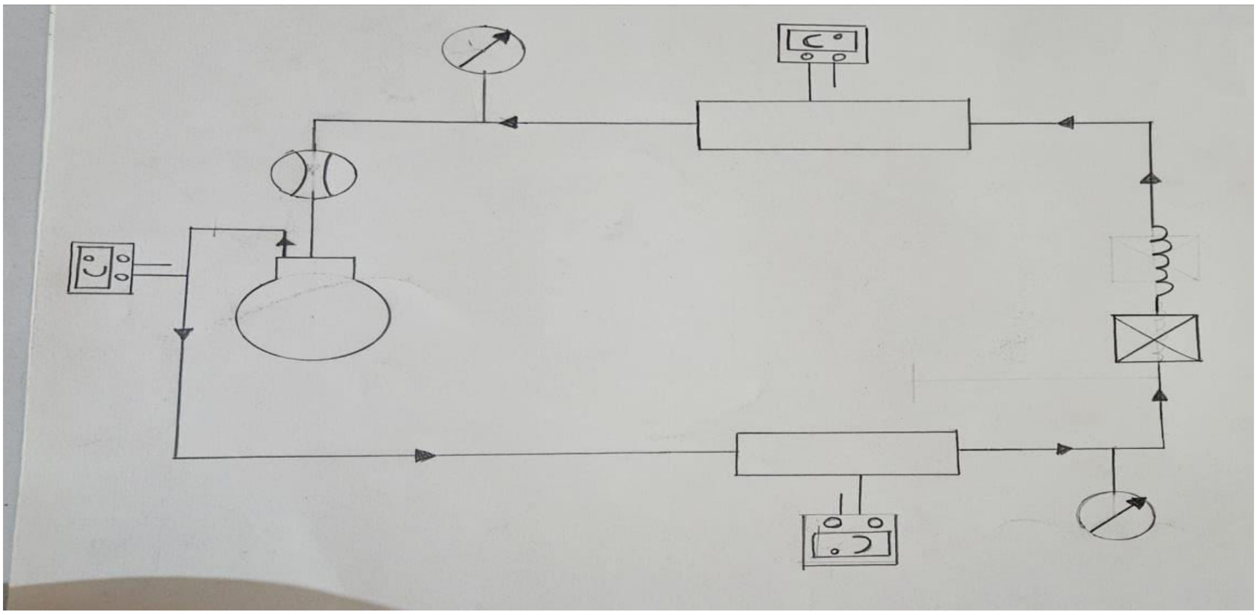


Fig 1. Introduction to ML

Additionally, achieving high accuracy is essential to minimize false positives and false negatives, ensuring that faults are correctly identified for timely maintenance. Another key factor is computational efficiency, as real-time diagnostics require fast processing speeds to reduce downtime and operational costs. Several ML approaches have been applied to refrigeration system fault detection, each with its own strengths and limitations. Convolutional Neural Networks (CNNs) are effective for recognizing patterns in sensor data but require large datasets and high computational power. Support Vector Machines (SVMs) have proven to be highly effective, offering high classification accuracy and good generalization for fault detection. Linear Discriminant Analysis (LDA) is useful for dimensionality reduction but lacks robustness in handling complex system variations. Studies have shown that SVM is the best-performing classifier, achieving 100% accuracy for most faults, except for non-faulty and expansion valve conditions, which had classification rates of 98% and 96%, respectively (Soltani et al., 2020). In contrast, LDA and LDA-SVM models, while accurate in detecting faults, exhibit reduced performance under varying conditions. CNN and PCA-SVM models performed poorly, mainly due to high computational demands and sensitivity to data variations. In industrial applications, ML-based FDD systems are increasingly being integrated into reefer containers, cold storage houses, and supermarket refrigeration systems. The future of ML in refrigeration systems lies in real-time fault detection, improved handling of transient conditions, and enhanced robustness through hybrid ML models.

© 2025 IJMRSET | Volume 8, Issue 4, April 2025| DOI:10.15680/IJMRSET.2025.0804209

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

III. WORKING SETUP IN REFRIGERATION SYSTEM FAULT DETECTION BY USING MACHINE LEARNING

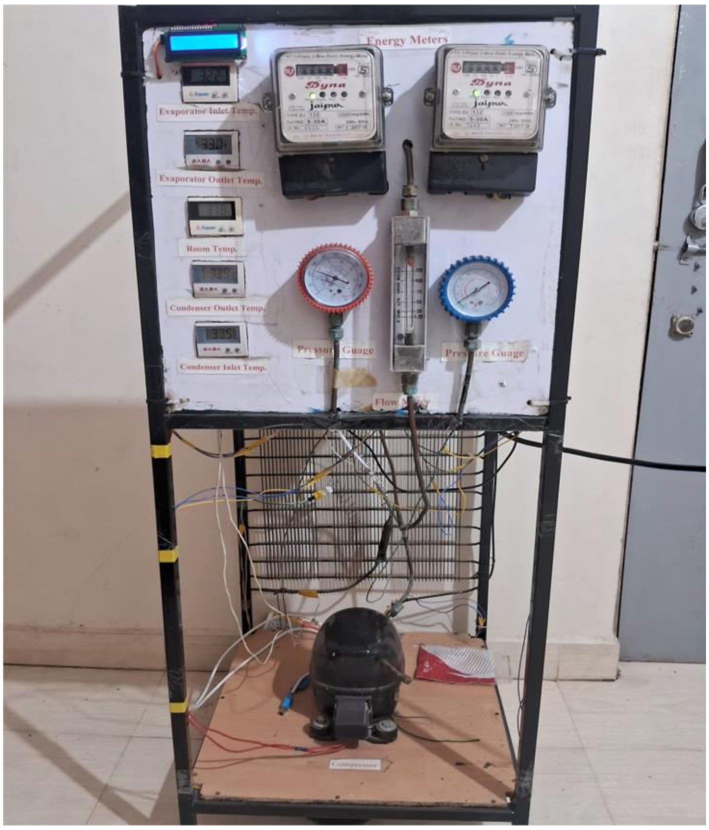


Fig. 2. Working model in Refrigeration System Fault Detection By Using Machine Learning

IV. MATERIAL AND COMPONENTS USED IN REFRIGERATION SYSTEM MODEL

The fault detection system for the refrigeration unit was developed using a combination of essential refrigeration hardware and modern electronic components. The primary refrigeration cycle consists of a hermetically sealed compressor, condenser, capillary tube, and evaporator, which facilitate the core cooling process. To enable real-time monitoring and intelligent fault detection, the system is equipped with three DHT22 sensors to measure temperature and humidity, and pressure gauges to monitor refrigerant pressure levels.

A flow meter is included to measure the refrigerant flow rate, and an energy meter is used to track power consumption. These components are integrated using an Arduino UNO R3 microcontroller, connected via jumper cables, and the processed data is displayed on a Liquid Crystal Display (LCD). An adapter provides consistent power supply to the system. This integration of traditional refrigeration components with sensor-based monitoring enables effective fault detection using machine learning algorithms.

V. APPLICATIONS OF REFRIGERATION SYSTEM FAULT DETECTION BY USING MACHINE LEARNING

The machine learning-based fault detection system in refrigeration has a wide range of applications across industrial, commercial, and healthcare sectors. It enables Fault Detection and Diagnosis (FDD) by identifying and classifying faults in key components such as compressors, condensers, and evaporators. Through predictive maintenance, it monitors system performance and anticipates failures, minimizing downtime and repair costs. The system also supports

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

energy efficiency optimization by dynamically adjusting cooling cycles and refrigerant flow. Automated control systems regulate temperature, pressure, and humidity without human input, while refrigerant leakage detection helps prevent environmental harm and performance loss. Applications extend to industrial cold storage**,** supermarket refrigeration, and smart HVAC systems**,** ensuring optimal conditions for perishable goods and indoor environments. Additionally, IoT-enabled remote monitoring allows real-time access and control via cloud platforms, and medical storage regulation ensures reliable cooling for sensitive pharmaceutical and biomedical products.

VI. EXPERIMENTAL VALIDATION

The Arduino IDE is an open-source software, which is used to write and upload code to the Arduino boards. The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux. It supports the programming languages C and Ct+. Here, IDE stands for Integrated Development Environment. The program or code written in the Arduino IDE is often called sketching, We need to connect the Arduino board with the IDE to upload the sketch written in the Arduino IDE software. The sketch is saved with the extension '.ino.'

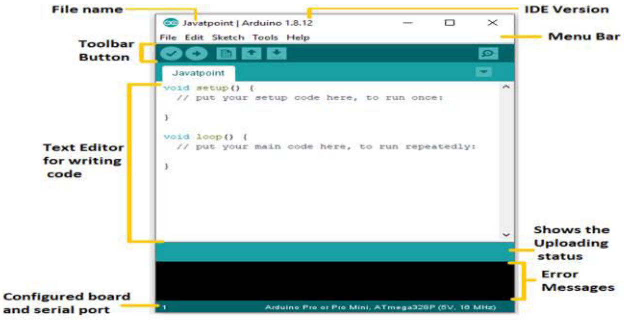


Fig. 3 Arduino Interface

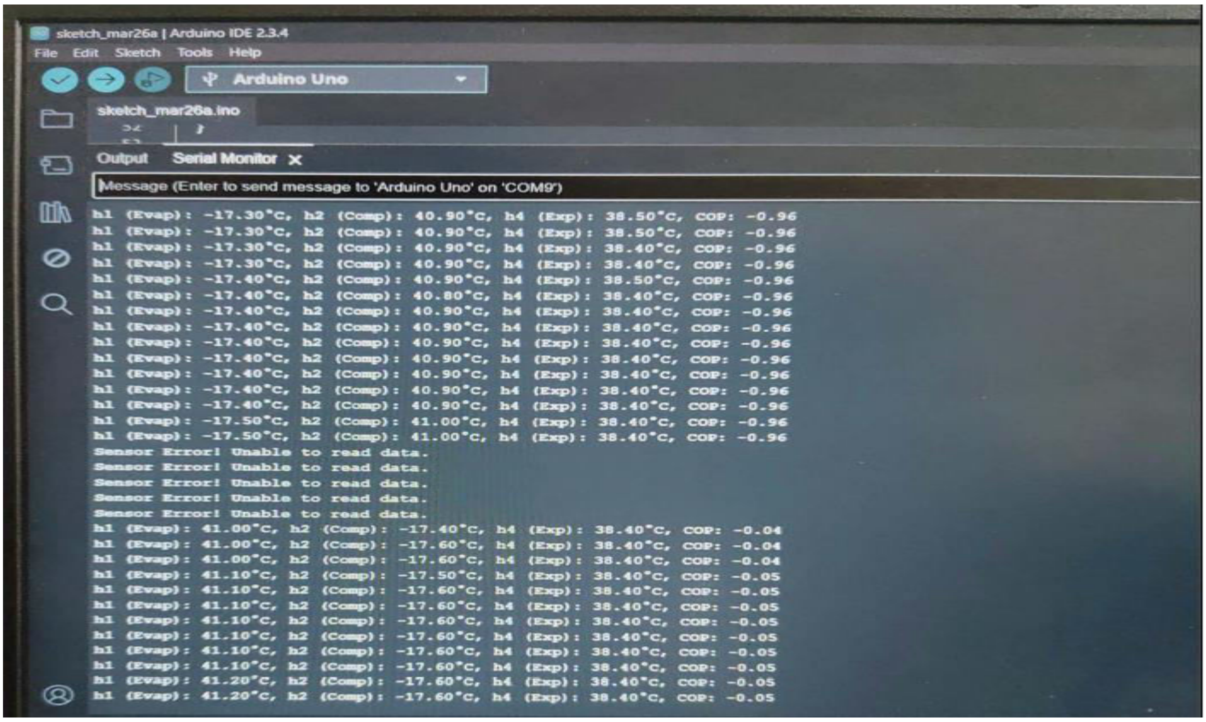


Fig. 4 Arduino Program Output Co-Ordinates

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

VII. CONCLUSION

This study presents a comprehensive approach to enhancing the performance, reliability, and sustainability of refrigeration systems through the integration of sensor-based monitoring and machine learning algorithms. Real-time data collected from DHT22 temperature and humidity sensors, pressure gauges, flow meters, and energy meters enabled accurate fault detection and system optimization. By applying advanced ML classifiers such as Support Vector Machine (SVM), Convolutional Neural Networks (CNN), and Linear Discriminant Analysis (LDA), the system effectively identified and diagnosed faults. Among these, SVM proved to be the most reliable due to its high classification accuracy and robustness in variable operating conditions. The implementation of predictive maintenance reduced unexpected failures and minimized operational costs, while also optimizing energy consumption by dynamically adjusting system parameters. The proposed setup is scalable and adaptable for industrial applications including cold storage warehouses, reefer containers, supermarkets, and medical refrigeration. This work emphasizes the role of digitalization in refrigeration technology, offering a practical, data-driven solution for smart monitoring. Ultimately, the integration of IoT and AI technologies contributes to improved energy efficiency, system longevity, and environmental sustainability in modern refrigeration systems.

REFERENCES

[1] Xu, X., Liu, J., & Sun, X.(2019). "Refrigerant leak detection for refrigeration system s A review of methods and technologies." Renewable and Sustainable Energy Reviews, 101, 482-494. This paper provides a com prehensive review of traditional and emerging refrigerant leak detection methods, including machine learning techniques for real-time monitoring and improved accuracy.

[2] Zhao, Y, & Zhang, M.(2021). "Machine learning for leak detection in refrigeration systems." Energy Reports, 7, 460-471 This study explores the use of machine learning methods, such as decision trees, neural networks, and ensemble models, for detecting refrigerant leaks in real-time, focusing on energy efficiency and system maintenance

[3] Ma, Z.. & Yana, x. (2020). "Application of artificial intelligence and machine learning in leak detection for refrigerant management." Energy and Buildings, 222 110114. The paper reviews the application of artificial intelligence (Al) and machine learning algorithms, such as neural networks and support vector machines, to monitor and detect refrigerant leaks in commercial and industrial settings.

[4] Liu, S, Wu, x., & Wang, L.(2018)."Data-driven approaches for refrigerant leak detection in HVAC systems using machine learning algorithms." Journal of Building Performance, 9(3), 77-88. This article discusses data-driven machine learning approaches for leak detection in HVAC and refrigeration systems, emphasizing the importance of sensor data fusion and time-series analysis.

INNO SPACE
SJIF Scientific Journal Impact Factor

ISSN
INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com