# DECLARATION

# APPROVAL PAGE

# ACKNOWLEDGEMENT

In the name of Allah, the most beneficent and merciful, it is my radiant sentiment to place on the record of my best regards to my dearest supervisor, Dr. Nur Farahwahida Binti Ab Aziz who took time out to hear, supervise, and guide me in completing my Final Year Project despite her hectic schedule. Dr. Nur Farahwahida has been a great supervisor as she always gives me her constructive and useful suggestions to my Final Year Project. I choose this moment to acknowledge her contribution gratefully. Without her encouragement and guidance, this project would not have materialised. The same goes for Ts Faridah Binti Yahya, who has been providing all the project guidelines and coordinating the final year project. Aside from that, I would like to express my heartiest gratitude to my parents and family who had supported me, encouraged me, and never give up on me in spite of my long years of studies. Whenever I was at the edge of giving up, they braced me up by keeping me happy and give me the strength to continue my project.

# ABSTRACT

*In the era of smart homes and Internet of Things (IoT) advancements, the maintenance of household appliances, particularly washing machines, demands innovative solutions to ensure their optimal performance and longevity. The "Predictive Maintenance of Smart Washing Machines" project aims to revolutionize traditional maintenance approaches by leveraging IoT, data analysis, and artificial intelligence. This project focuses on developing a predictive maintenance system tailored specifically for smart washing machines, transitioning from reactive to proactive maintenance strategies. By integrating various sensors to monitor parameters such as energy consumption, vibration patterns, and temperature fluctuations, real-time data will be collected and analysed using advanced algorithms to detect anomalies and predict potential failures. The project includes the design of a user-friendly interface, enabling homeowners to access real-time insights into their washing machines' health status, facilitating informed decision-making. Additionally, rigorous testing and validation will be conducted to evaluate the system's effectiveness in real-world scenarios. The proposed predictive maintenance system aims to enhance appliance reliability, reduce maintenance costs, and improve user satisfaction by preventing costly repairs and minimizing downtime. Through this comprehensive approach, the project seeks to set a new standard for smart appliance maintenance, contributing to the broader adoption and effectiveness of smart home technologies.*

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# LIST OF ABBREVIATIONS

|  |  |  |
| --- | --- | --- |
| **Abbreviation** |  | **Descriptions** |
| CBM | - | Condition-Based Maintenance |
| CNNs | - | Convolutional Neural Networks |
| FFT | - | Fast Fourier Transform |
| FO-SVM | - | Feature Oriented Support Vector Machine |
| IoT | - | Internet of Things |
| IWSNs | - | Industrial Wireless Sensor Networks |
| MCSA | - | Motor Current Signature Analysis |
| MQTT | - | Message Queuing Telemetry Transport |
| NN | - | Neural Network |
| PdM | - | Predictive Maintenance |
| PHM | - | Prognostics and Health Management |
| QoS | - | Quality of Service |
| RMS | - | Root Mean Square |
| RNNs | - | Recurrent Neural Networks |
| RUL | - | Remaining Useful Life |
| SVM | - | Support Vector Machines |
| WBS | - | Work Breakdown Structure |

# :INTRODUCTION

## Introduction

In the era of smart homes and Internet of Things (IoT) advancements, the maintenance of washing machines, whether in households or commercial settings like self-service laundries, has taken a significant leap forward. The "Predictive Maintenance of Smart Washing Machines" project aims to revolutionize the maintenance approach for these essential appliances. Leveraging the power of IoT, data analysis, and artificial intelligence, this project seeks to develop a cutting-edge predictive maintenance system tailored specifically for smart washing machines. As the adoption of smart technologies continues to rise, there is a growing need for innovative solutions that not only enhance appliance performance but also optimize maintenance processes to ensure longevity and reliability, especially in environments with multiple machines and high usage.

## 1.2 Problem Statement

Traditional maintenance methods for washing machines are reactive, leading to unplanned downtime and high repair costs. The growing complexity of smart washing machines requires more advanced maintenance strategies that can predict issues before they occur. Self-service laundry businesses face challenges in managing and maintaining multiple machines simultaneously without constant supervision.

## 1.3 Project Objectives

The objectives of this project is to:

1. **to develop Predictive Maintenance System using IoT Sensors**: Utilize IoT sensors to monitor vibration, temperature, and energy consumption.
2. **to implement Data Processing and Machine Learning Algorithms**: Analyse sensor data with advanced data processing and machine learning algorithms.
3. **to create User-Friendly Interface for Real-Time Monitoring and Alerts**: Design an intuitive interface for real-time monitoring and maintenance alerts.

## 1.4 Project Scope

The scope of this project is broad and includes everything from conception to execution:

1. **Sensor Integration:** Integrate sensors to monitor energy consumption, vibration, and temperature in smart washing machines.
2. **Data Processing and Analysis:** Transmit sensor data to a centralized platform for analysis using advanced algorithms to detect anomalies and predict failures.
3. **Fault Prediction and Maintenance Scheduling:** Generate maintenance alerts and recommendations based on data analysis to schedule preventive actions and extend machine lifespan.
4. **User Interface Development:** Design a user-friendly interface for web and mobile platforms to visualize machine health, receive notifications, and manage maintenance remotely.
5. **Technological Integration:** Use IoT technologies, MQTT protocol, and machine learning libraries to build the predictive maintenance system.
6. **Cost Considerations:** Account for expenses related to hardware, software tools, testing equipment, and prototyping materials.

## 1.5 Significance of project

This project benefits both self-service laundry business owners and household users by providing a proactive maintenance solution that ensures the optimal performance and longevity of smart washing machines. Business owners will save time and money by avoiding costly repairs and minimizing downtime through real-time monitoring and predictive maintenance. Household users will benefit from enhanced reliability and reduced inconvenience. Additionally, the system's user-friendly interface allows for easy monitoring and control, improving the overall operational efficiency and enhancing the reliability of washing machines.

## 

## 1.6 Expected Outcome

The expected outcomes of this project are:

1. Improved quality and reliability of smart washing machines through proactive maintenance strategies.
2. Reduction in maintenance costs and downtime by predicting and preventing potential failures.
3. Enhanced user experience with a user-friendly interface providing real-time insights and remote-control capabilities.
4. Increased lifespan of smart washing machines, ensuring better return on investment for business owners and improved convenience for household users.

## 1.7 Project Limitation

One of the limitations of this project is the reliance on the quality and accuracy of the sensors used. The prototype may use sensors and instrumentation that are not industrial-grade due to budget constraints, which could impact data accuracy and system performance. Additionally, the system's effectiveness depends on the robustness of the communication protocols, including the MQTT protocol, and the reliability of the centralized data processing platform. Ensuring compatibility with various smart washing machine models and user devices also presents a challenge that needs to be addressed.

# :LITERATURE REVIEW

## 2.1 Introduction

An essential part of this study is the literature review, which focuses on studies in the field of predictive maintenance for intelligent washing machines. An overview of the state-of-the-art in predictive maintenance will be given in this chapter, along with a comparison of the suggested predictive maintenance system with Internet of Things (IoT) technology and conventional maintenance techniques. A particular focus will be on the technology and hardware used in the development of the suggested system.

Traditional washing machine maintenance procedures have a number of disadvantages that reduce their usefulness in homes. These problems include estimating and manually controlling the amount of water used in washing cycles, as well as accurately dispensing detergents and additives. Furthermore, the longevity and functionality of the machine may be negatively impacted by specific detergents. Moreover, the conventional maintenance method is linked to substantial expenses with the usage of water and detergent.

Through the use of sensor technology, the Predictive Maintenance on Smart Washing Machine is an integrated hardware and software solution that enables users to remotely monitor and control the performance of washing machines. The following goals are intended to be attained by this system:

1. to implement a system that prevents and detects these failures by continuously monitoring machine operation parameters like energy consumption, vibration, and temperature patterns. Abnormal variations in these data will indicate potential issues, enabling reactive and predictive maintenance actions.
2. Develop a new business model that enhances maintenance efficiency by leveraging predictive maintenance capabilities. This system aims to resolve problems more efficiently and even predict failures before they occur, ensuring timely repairs and better appliance performance.
3. Overcome data accessibility challenges by utilizing external sensors to collect operational data. Design the architecture to accommodate IoT-enabled appliances in the future, ensuring compatibility with evolving technology standards.

## 2.2 Background Study

With the introduction of smart home technologies in recent years, traditional household devices have evolved into complex machinery with remote monitoring and autonomous operation capabilities. Among these advancements, smart washing machines have become essential parts of modern homes thanks to their superior sensor technology and connectivity, which improve efficiency and ease.  
 Even though smart washing machines have many benefits, typical maintenance procedures for these devices frequently depend on reactive repairs or regular servicing, which can result in inefficiencies and unplanned downtime for consumers. Additionally, early wear of machine parts and higher maintenance costs may arise from the inability to anticipate component failures in advance.

Predictive maintenance (PdM) is a concept that has gained a lot of popularity in industrial settings. It uses machine learning algorithms and data-driven insights to monitor the health of machinery in real-time and predict future problems before they happen. Predictive maintenance methods haven't been used to consumer products like smart washing machines too often, though.

Several important issues highlight the need of predictive maintenance in the context of smart washing machines:   
**Enhanced Reliability:** Predictive maintenance allows smart washing machines to proactively detect possible problems and act before they worsen, which improves overall performance as well as reliability.   
**Cost Optimisation:** By avoiding unnecessary component replacements, predictive maintenance can improve maintenance schedules, lower repair costs, and increase the lifespan of smart washing machines.   
**User Experience:** By reducing maintenance-related downtime and interruptions, smart washing machines can greatly improve customer satisfaction.   
**Technological Advancement:** Predictive maintenance for household appliances is in line with the larger trend of adopting cutting-edge technologies to enhance the functioning and efficiency of everyday products.

By creating and putting into effect a predictive maintenance framework designed specifically for this situation, this study seeks to fill in the gap in predictive maintenance applications for smart washing machines. The system requires to advance smart home technology and household appliance maintenance practices by using sensor data and machine learning algorithms to facilitate real-time monitoring, early fault detection, and improved maintenance scheduling for smart washing machines.

## 2.3 Review on Existing Systems

In order to give a structured overview, the literature review is divided into multiple subtopics:

### 2.3.1 Predictive Maintenance (PdM)

Predictive maintenance (PdM) has become an essential component of Industry 4.0, significantly enhancing the efficiency and reliability of manufacturing systems. PdM focuses on the proactive monitoring and maintenance of equipment by leveraging data analytics, IoT technologies, and machine learning. The primary goal of PdM is to minimize machine downtime, reduce maintenance costs, and extend the lifespan of equipment. It involves methodologies such as Condition-Based Maintenance (CBM), Prognostics and Health Management (PHM), and Remaining Useful Life (RUL) estimation.

CBM involves real-time monitoring of machine conditions to perform maintenance only when necessary. PHM aims to assess the health of equipment and predict future failures, while RUL estimation forecasts the remaining operational time before maintenance is required. These methodologies rely heavily on data collected from various sensors integrated into the equipment. Advanced algorithms process this data to predict potential failures and schedule maintenance activities proactively [1].

A graph with numbers and a bar

Description automatically generated

Figure 2.1: Size of Maintenance 4.0 market worldwide in 2020 and 2021 with forecast for future years (from 2022 to 2030)

Predictive maintenance in the context of smart washing machines involves integrating sensors to monitor various operational parameters, such as vibration, energy consumption, and motor health. The data collected is then analysed to detect anomalies and predict faults before they occur, ensuring continuous and efficient operation. Figure 2.1 illustrates the global trend towards the adoption of predictive maintenance solutions, highlighting the projected market growth from 2022 to 2030 [1]. It provides a clear visual representation of the increasing adoption and importance of predictive maintenance in various industries, aligning with the project's objective to implement advanced maintenance strategies for smart washing machines.

### 2.3.2 Vibration Pattern Recognition

Vibration pattern recognition plays a critical role in predictive maintenance, especially for diagnosing faults in rotating machinery. Vibration signals can provide valuable insights into the operational health of a machine. Traditional Fourier Transform (FFT) methods are commonly used to analyse these signals. However, FFT is limited in its ability to analyse non-stationary signals, which are common in real-world applications.

Recent advancements have introduced the use of internet of things (IoT) technologies combined with industrial wireless sensor networks (IWSNs) for vibration monitoring. These systems enable continuous, real-time monitoring and early fault detection. The proposed approach in recent research employs Feature Oriented Support Vector Machine (FO-SVM) algorithms to extract relevant features and classify faults accurately. This method improves the efficiency of fault detection and reduces the dimensionality of the feature set, making it suitable for cloud-based processing and real-time applications [3].

A diagram of a router

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Figure 2.2: Functional structure of industrial wireless sensor networks

Figure 2.2 shows the functional structure of the industrial wireless sensor networks system for vibration data acquisition and monitoring, which is integral to implementing an effective vibration pattern recognition system in smart washing machines [3].

### 2.3.3 Energy Consumption

Monitoring energy consumption is crucial for optimizing the performance and maintenance of smart washing machines. Continuous tracking of energy usage patterns helps in identifying anomalies that could indicate inefficiencies or potential faults. This proactive approach not only enhances machine efficiency but also reduces operational costs significantly.

The integration of IoT technologies and advanced sensors plays a pivotal role in collecting and analysing energy consumption data. These sensors provide real-time data on energy usage, which is then processed using advanced algorithms to detect deviations from normal patterns. Early detection of such anomalies allows for timely maintenance interventions, preventing major failures and ensuring the efficient operation of washing machines [4].

### 2.3.4 Electric Motor Monitoring

Electric motor monitoring is a vital component of predictive maintenance for washing machines. Motors are critical parts of washing machines, and their failure can lead to significant downtime and repair costs. Motor Current Signature Analysis (MCSA) is a widely recognized technique used for detecting faults in electric motors. This method involves analysing the current spectrum of the motor to identify issues such as stator winding faults, bearing faults, and broken rotor bars.

MCSA is advantageous due to its non-invasive nature and its capability to provide real-time monitoring. By analysing variations in the stator current spectrum, MCSA can differentiate between healthy and faulty conditions of the motor. This technique has been successfully applied in various industrial applications, proving its effectiveness in early fault detection [2].

A diagram of data acquisition process

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Figure 2.3: Block diagram of methodology for fault detection in Induction Machine using MCSA

Figure 2.3 presents the block diagram of the methodology for fault detection in induction machines using MCSA. The process starts with signal measurement by transducers, followed by data acquisition and analysis using appropriate signal processing techniques. By comparing the faulty current spectrum with the healthy spectrum, faults in the induction machine can be detected accurately. This method not only improves the reliability of motor operations but also extends the lifespan of the equipment by enabling timely maintenance interventions [2].

### 2.3.5 Fault Diagnostics

Fault diagnostics is a cornerstone of predictive maintenance, involving the detection and analysis of faults within machinery. Effective fault diagnostics relies on various signal analysis techniques, including time-domain and frequency-domain methods. Machine learning techniques have become increasingly popular for fault diagnostics due to their ability to handle complex data and improve diagnostic accuracy.

Machine learning algorithms such as Support Vector Machines (SVMs), Neural Networks (NNs), and Decision Trees are commonly used in fault diagnostics. These algorithms analyse historical and real-time data to identify patterns indicative of faults. The application of deep learning techniques, particularly Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), has further enhanced the capabilities of fault diagnostics by enabling the automatic extraction of features from raw data [5].

A diagram of data collection

Description automatically generated

Figure 2.4: Diagnosis process of IFD using deep learning theories

The researcher provided a comprehensive review of the applications of machine learning to machine fault diagnosis. [5] The study discusses various machine learning techniques used for fault diagnostics and their effectiveness in different industrial applications. The integration of machine learning with IoT technologies allows for real-time monitoring and fault detection, which is crucial for the predictive maintenance of smart washing machines. Figure 2.4 illustrates the process of intelligent fault diagnosis using deep learning theories, showcasing the steps involved from data collection to fault identification [5]. It provides a detailed visualization of the fault diagnosis process using machine learning, which is central to the project's approach to predictive maintenance.

## 2.4 Summary of Literature Review

Table 2.1: Summary of Literature Review

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Paper Title (Year Published) | Similarities with Current Project | Differences with Current Project | Advantages | Disadvantages |
| On Predictive Maintenance in Industry 4.0: Overview, Models, and Challenges. (2022) | Uses IoT sensors and machine learning algorithms for data analysis | The current project is specific to washing machines, whereas general PdM can be applied to various industrial machines | Reduces downtime, maintenance costs, extends equipment life [1] | Requires high-quality data and robust algorithms; implementation complexity [1] |
| Research on vibration monitoring and fault diagnosis of rotating machinery based on internet of things technology. (2021) | Analyses vibration data to detect anomalies and faults | Focused application on washing machine components | Provides early detection of mechanical issues, improving maintenance scheduling [3] | Requires additional sensors and advanced data processing; susceptible to external noise [3] |
| A review on energy consumption optimization techniques in IoT based smart building environments. (2019) | Monitors and optimizes energy usage patterns | Specifically targets energy efficiency in washing machines | Leads to cost savings and environmental benefits through energy efficiency [4] | Optimization may conflict with performance needs; implementation complexity [4] |
| Motor Current Signature Analysis for Fault Detection of Induction Machine–A Review. (2021) | Monitors key parameters of electric motors to detect issues | Uses MCSA specifically for washing machine motors | Early detection of motor-related problems, preventing severe failures [2] | Requires continuous monitoring and advanced signal processing; sensor failures can affect reliability [2] |
| Applications of machine learning to machine fault diagnosis: A review and roadmap. (2020) | Identifies and classifies faults using advanced methodologies | Applies advanced machine learning techniques like CNNs and RNNs to washing machines | Enhances accuracy and speed of fault identification, reducing downtime [5] | Requires comprehensive training data; high computational resources needed for real-time diagnostics [5] |

# :METHODOLOGY

## 3.1 Introduction

During research, the methodology is the most important part. Methodology refers to a documented process or step-by-step approach used to aid in developing a successful project. This chapter discusses the phases required to understand the research objectives as stated in Chapter 1. The project methodology explains the requirements, design, implementation, verification, and maintenance. The chosen methodology can help determine suitable methods for implementation, testing, and documenting the project intended to be developed.

## 3.2 The Methodology Model

The Agile methodology has been chosen for this project due to its iterative and flexible approach. Agile is suitable for projects that require continuous improvement and stakeholder involvement throughout the development process. Agile focuses on incremental progress through repeated cycles or sprints, allowing for regular feedback and adjustments. Therefore, the “Predictive Maintenance on Smart Washing Machine” is suitable for implementing the Agile methodology.

A diagram of a process

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Figure 3.1: Agile Methodology

## 3.3 Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) for the project is detailed below, providing a hierarchical decomposition of the work required to complete the project.

A screenshot of a diagram

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Figure 3.2: Work Breakdown Structure

## 3.4 Project Cost

The project cost is outlined below, detailing the budget for hardware and software components.

Table 3.1: Project Costing for Hardware Requirements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Hardware Components | Unit | Price Per Unit (MYR) | Total (MYR) |
| 1 | ESP32 | 1 | 40.00 | 40.00 |
| 2 | SW-420 Vibration Sensor | 1 | 20.00 | 20.00 |
| 3 | PT100 Temperature Sensor | 1 | 32.00 | 32.00 |
| 4 | ZMPT101B AC Voltage Sensor Module | 1 | 28.00 | 28.00 |
| 5 | SCT-013-030 Non-invasive AC Current Sensor | 1 | 40.00 | 40.00 |
| 6 | 5V 2-Channel Relay Module | 1 | 20.00 | 20.00 |
| 7 | Mini Smart Washing Machine | 1 | 200.00 | 200.00 |
| 8 | Miscellaneous Components | 1 | 80.00 | 80.00 |
| Total Cost (MYR) |  |  |  | 460.00 |

Table 3.2: Project Costing for Software Requirements

|  |  |  |
| --- | --- | --- |
| No | Software Components | Price (MYR) |
| 1 | RapidMiner | Free |
| 2 | Node-RED | Free |
| 3 | Arduino IDE | Free |
| 4 | Thonny | Free |
| 5 | MIT App Inventor | Free |

## 3.5 Gantt Chart

A Gantt chart is used to develop the project schedule, illustrating the start and end dates of each phase along with their sub-tasks. The elements in the Gantt chart follow the tasks created in the Work Breakdown Structure. The Gantt chart for this project is included in Appendix B.

## 3.6 System Requirement Analysis

To create the Predictive Maintenance on Smart Washing Machine system, the hardware and software must be carefully chosen. The selected hardware and software are listed below.

### 3.6.1 Hardware Requirements

i. ESP32 DevKit

A close-up of a computer chip

Description automatically generated

Figure 3.3: ESP32 DevKit

The ESP32 DevKit is the microcontroller for data acquisition and transmission.

ii. SW-420 Vibration Sensor

A blue circuit board with a blue capacitor and a blue light

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Figure 3.4: SW-420 Vibration Sensor

The SW-420 Vibration Sensor is used to monitor vibration patterns.

iii. PT100 Temperature Sensor

A close-up of a temperature sensor

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Figure 3.5: PT100 Temperature Sensor

The PT100 Temperature Sensor measures temperature inside the washing machine.

iv. ZMPT101B AC Voltage Sensor

A blue electronic device with a blue square

Description automatically generated

Figure 3.6: ZMPT101B AC Voltage Sensor

The ZMPT101B AC Voltage Sensor is used to track voltage levels.

v. SCT-013-030 Non-invasive AC Current Sensor

A blue device with a black cable

Description automatically generated

Figure 3.7: SCT-013-030 Non-invasive AC Current Sensor

The SCT-013-030 Non-invasive AC Current Sensor monitors the current consumption.

vi. 5V 2-Channel Relay Module

A blue and black electronic device

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Figure 3.8: 5V 2-Channel Relay Module

The 5V 2-Channel Relay Module is used to control switching actions.

vii. Mini Smart Washing Machine

The Mini Smart Washing Machine is used for testing and validation.

### 

### 3.6.2 Software Requirements

Table 3.3: Software Requirements

|  |  |
| --- | --- |
| Software | Description |
| RapidMiner | Machine learning model development |
| Node-RED | Dashboard creation and visualization |
| Arduino IDE | Coding and programming the ESP32 |
| Thonny | Coding and programming the ESP32 |
| MIT App Inventor | Mobile App Development |

## 3.7 Data Acquisition and Transmission

Data acquisition involves continuously collecting data from the integrated sensors. This data is then transmitted to a centralized server using the MQTT protocol, known for its lightweight nature and suitability for IoT applications. The key steps involved in data acquisition and transmission are:

1. **Data Collection**: The sensors collect real-time data on vibration, energy consumption, and temperature. The data is sampled at high frequencies to capture detailed operational characteristics.
2. **Microcontroller Interface**: The ESP32 microcontroller interfaces with the sensors, processes the raw data, and formats it for transmission.
3. **Data Transmission**: The formatted data is transmitted to the centralized server over a secure IoT network using the MQTT protocol. This ensures efficient and reliable data transmission, with features like Quality of Service (QoS) levels and retained messages to handle varying network conditions.
4. **Data Security**: To ensure data integrity and confidentiality, the transmission process uses TLS encryption and authentication mechanisms. These measures protect the data from unauthorized access and tampering during transit.

## 3.8 Data Processing and Analysis

Upon reaching the server, the data undergoes several processing steps to prepare it for analysis. These steps include:

1. **Data Filtering**: The raw sensor data is filtered to remove noise and irrelevant information. Techniques such as low pass filtering and outlier detection are employed to enhance data quality.
2. **Data Aggregation**: The filtered data is aggregated to reduce redundancy and highlight significant patterns. Aggregation involves summarizing data points over specific intervals, such as calculating average energy consumption or peak vibration levels.
3. **Feature Extraction**: Relevant features are extracted from the processed data to facilitate effective machine learning. For example, statistical features like mean, standard deviation, and kurtosis are computed for vibration signals, while trends and seasonal patterns are identified in energy consumption data.

## 3.9 Machine Learning Model Development

The core of the predictive maintenance system is the machine learning model. The development process involves several steps:

1. **Data Preprocessing**: The data is pre-processed to handle missing values, normalize ranges, and create relevant features. Preprocessing ensures the data is clean and suitable for training machine learning models.
2. **Feature Engineering**: Key features are extracted from the data, such as the Root Mean Square (RMS) of vibration signals, energy consumption rates, and temperature variations. Feature engineering transforms raw data into informative attributes that enhance model performance.
3. **Model Training**: Machine learning algorithms, including SVMs, NNs, and Decision Trees, are trained using historical data to learn patterns associated with normal and faulty operations. Training involves selecting appropriate hyperparameters and optimizing the models to minimize prediction errors.
4. **Model Validation**: The trained models are validated using a separate dataset to evaluate their accuracy, robustness, and generalization capabilities. Cross-validation techniques and performance metrics like precision, recall, and F1-score are used to assess model quality.
5. **Model Deployment**: The validated models are deployed to the server, where they analyse real-time data to predict potential failures. The deployment process includes setting up inference pipelines and integrating the models with the data processing framework.

## 3.10 Fault Detection and Prediction

The deployed machine learning models continuously analyse the incoming data to detect anomalies and predict faults. When a potential issue is identified, the system generates an alert and provides recommendations for preventive maintenance actions. The fault detection and prediction process involve:

1. **Anomaly Detection**: The models monitor the data streams for deviations from normal behaviour. Anomalies are identified based on predefined thresholds and statistical properties of the data.
2. **Fault Classification**: Detected anomalies are classified into specific fault types using machine learning classifiers. The classification helps in understanding the nature and severity of the issue.
3. **Maintenance Recommendations**: Based on the classified faults, the system generates maintenance recommendations, such as scheduling inspections, replacing components, or adjusting operational parameters. These recommendations are aimed at preventing failures and optimizing machine performance.

## 3.11 Block Diagram

A block diagram illustrating the system architecture and component interactions is included to provide a visual overview of the system.

A diagram of a computer

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Figure 3.9: Block Diagram

## 3.12 Flowchart

A detailed flowchart outlining the step-by-step process of the system is included to provide a clear understanding of the system's workflow.

A diagram of a data flow

Description automatically generated

Figure 3.10: Flowchart

## 3.13 Circuit Diagram

A circuit diagram showing the wiring and connections between different hardware components is included to assist in the implementation phase.

A circuit board with wires

Description automatically generated

Figure 3.11: Circuit Diagram

# :RESULT AND DISCUSSION

## 4.1 Introduction

## 4.2 Project Testing and Result

## 4.3 Discussion

# :CONCLUSION

## 5.1 Introduction

## 5.2 Objective Achievement

## 5.3 Summary

# REFRENCES

1. Achouch, M., Dimitrova, M., Ziane, K., Sattarpanah Karganroudi, S., Dhouib, R., Ibrahim, H., & Adda, M. (2022). On Predictive Maintenance in Industry 4.0: Overview, Models, and Challenges. Applied Sciences, 12(8081).
2. Bhole, N., & Ghodke, S. (2021). Motor Current Signature Analysis for Fault Detection of Induction Machine–A Review. 2021 International Conference on Nascent Technologies in Engineering (ICNTE 2021).
3. Zhang, X., Rane, K. P., Kakaravada, I., & Shabaz, M. (2021). Research on vibration monitoring and fault diagnosis of rotating machinery based on internet of things technology. Nonlinear Engineering, 10(1), 245-254.
4. Shah, A. S., Nasir, H., Fayaz, M., Lajis, A., & Shah, A. (2019). A review on energy consumption optimization techniques in IoT based smart building environments. Information, 10(3), 108.
5. Lei, Y., Yang, B., Jiang, X., Jia, F., Li, N., & Nandi, A. K. (2020). Applications of machine learning to machine fault diagnosis: A review and roadmap. Mechanical Systems and Signal Processing, 138, 106587.

# APPENDIX A: WORK BREAKDOWN STRUCTURE

A screenshot of a diagram

Description automatically generated

Figure A.1: Work Breakdown Structure (WBS)

# APPENDIX B: GANTT CHART

A graph with a bar

Description automatically generated with medium confidence

Figure B.1: Gantt Chart

# APPENDIX C