DEVELOPMENT OF LOW-COST VIBRATION MONITORING SOFTWARE SYSTEM WITH IOT

ZULFEKA HAKIMIE BIN ZULKIFLY

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Zulfeka Hakimie Bin Zulkifly

Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

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in fulfillment of the requirements for the degree of
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DEDICATION

Dedicated, grateful and thankful appreciation for support, encouragement, and understanding to my beloved father, mother, and sisters.

Whose support, encouragement, and prayers throughout the day and night enable me to achieve such accomplishment and honour.

Project supervisor, Ts. Dr. Mohd Irman Bin Ramli

Co-supervisor, Ts. Dr. Ahmad Fuad Bin Ab Ghani

Along with everyone who is related and most well

Lectures and friends

ABSTRACT

The study of mechanical vibration are important to this work. This project develops a low-cost vibration monitoring system to measure the vibration of the intended equipment and show the trend in Blynk IOT applications. This low-cost vibration monitoring system relies on the Hibiscus Sense, an accelerometer GY-521 MPU6050, and a 5000mAh battery bank. The microprocessor, accelerometer MPU6050, and temperature sensor BME280 are all built into the ESP32 development board that is the Hibiscus Sense. It was an Internet-of-Things technology that can share information using radio frequency networks like Wi-Fi and Bluetooth Low Energy (BLE). Hibiscus Sense's microprocessor handles the on-board MPU6050 and GY-521 MPU6050 accelerometers and transmits their readings through Wi-Fi to the Blynk app. The motor's vibrations are measured using three MPU6050s. This low-cost vibration monitoring device also uses the Arduino IDE and Blynk software as its interface programmes. Blynk is used to show the received data in gauge form and trend form for vibration analysis, while the Arduino IDE is used to develop the code to run the system.

ABSTRAK

Kajian getaran mekanikal adalah penting untuk kerja ini. Projek ini membangunkan sistem pemantauan getaran kos rendah untuk mengukur getaran peralatan yang dimaksudkan dan menunjukkan arah aliran dalam aplikasi Blynk IOT. Sistem pemantauan getaran kos rendah ini bergantung pada Hibiscus Sense, *accelerometer* GY-521 MPU6050 dan bank kuasa 5000mAh. Mikropemproses, *accelerometer* MPU6050, dan sensor suhu BME280 semuanya terbina dalam papan pembangunan ESP32 iaitu Hibiscus Sense. Ia adalah teknologi IOT(*Internet-of-Thing)s* yang boleh berkongsi maklumat menggunakan rangkaian frekuensi radio seperti Wi-Fi dan Bluetooth. Mikropemproses Hibiscus Sense mengendalikan *accelerometer* MPU6050 dan GY-521 MPU6050 *on-board* serta menghantar bacaannya melalui Wi-Fi ke apl Blynk. Getaran motor diukur menggunakan tiga MPU6050s. Peranti pemantauan getaran kos rendah ini juga menggunakan perisian Arduino IDE dan Blynk sebagai program antara mukanya. Blynk digunakan untuk menunjukkan data yang diterima dalam bentuk tolok dan bentuk aliran untuk analisis getaran, manakala Arduino IDE digunakan untuk membangunkan kod untuk menjalankan sistem.

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LIST OF SYMBOLS AND ABBREVIATIONS

a	-	Acceleration
FFT	-	Fast Fourier Transform
MEMS	-	Micro-Electro-Mechanical System
kHz	-	Kilohertz
IC	-	Intergrated Circuit
SoC	-	System-On-Chip
IoT	-	Internet Of Thing
IDE	-	Intergrated Developement Environment
t	-	Time
temp	-	Temperature

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CHAPTER 1

INTRODUCTION

1.1 Background

Most equipment in industrial plants is mechanical, vibration analysis is the most often used technique of predictive maintenance programmes. This method uses measurements of both noise and vibration levels to assess the health of a mechanical system's individual parts.(Juan Carlos et al.2020). The technology used for measuring vibrations is less than 100 years old. In addition to this, it has rapidly become important in many fields, including production, healthcare, mobile devices, and more. Modern methods for determining the origin, magnitude, and frequency of vibration are widely used, especially in industrial and commercial settings where asset failure can lead to financial losses or health problems.(PRUFTECHNIK, 2022).

One of the most extensively utilised condition monitoring techniques is vibration-based health assessment of industrial machinery. The primary reason for this is that the vibration signature of any given machine or structure may be immediately related to the health of the machine as a whole or any of its individual parts for example bearings, rotors, impellers, blades and gears. An important advantage of vibration-based monitoring is that the excited frequencies can be used to diagnose a wide variety of machine problems, including imbalance, misalignment, looseness, broken rotor bars, gear wear/breakage, damaged couplings, bearing faults, and many others. (A. Yunusa et al. 2014)

Machine vibrations generate complex signals that have no one linear form but are instead made up of several signals that are correlated with one another but have distinct frequencies, amplitudes, and phases. There are also waves whose waveform makes no sense at all. Because of their connection, signals must be analysed using mathematical procedures. The termed spectral analysis, which is based on the separation of the harmonic components of the vibratory signal, is the primary tool for the application of vibration analysis to predictive maintenance, as it allows the identification of the causes and effects of vibrations present in the operation of a machine. The Fourier series and the fast Fourier transform (FFT) are the foundation of spectral analysis. This sort of analysis is performed using electronic instruments and specialised computer equipment in a commercial setting. Understanding the fundamentals of spectrum analysis is important to getting the most out of your measuring tools. (Juan Carlos et al. 2020)

1.2 Problem Statement

In now days small industries face challenges in implementing industrial vibration monitoring systems due to the high cost of vibration monitoring system, which hinders effective machine health inspection. Therefore, it is a must needed for a low-cost vibration monitoring system that can be easily adopted by small industries for machine health checks. Various low-cost vibration sensors are available in the market, with Arduino being a popular coding software used to control these sensors. In this project, the hibiscus sense ESP32 and the MPU6050 vibration sensor will be utilized to collect vibration data from machines using commands programmed in the Arduino IDE software. The collected data will be visualized in the Blynk IOT application for vibration analysis.

Furthermore, the reliability and sensitivity of data obtained from low-cost vibration sensors may raise concerns among the public. To address this, a data validation process will be conducted by comparing the results obtained from the low-cost vibration monitoring sensors and the machine of vibration monitoring that have in the market. This comparative analysis will enable the assessment of accuracy and sensitivity among the sensors.

Additionally, unexpected breakdowns of machine components can cause disruptions in industrial production lines. Hence, a low-cost vibration monitoring system is crucial for early detection and prevention of such a sudden breakdown. By identifying out-of-balance, misaligned, worn-out, or loose machine parts, the low-cost vibration monitoring system can provide early warnings to the industry, by helping to prevent costly machine failures and production line slowdowns or stop from the production. Moreover, the low-cost system offers cost advantages over traditional industrial vibration monitoring systems for maintenance checks.

1.3 Research Objective

The objectives of this project are:

a) To produce and verify a low-cost vibration monitoring system for three axis

b) To conduct the software development for low-cost vibration monitoring system

1.4 Scope of Research

The scope of research are as follows:

a) Monitoring the vibration for the machine

b) Arduino IDE software and Blynk iot software will be use.

c) The frequency range that can be detected is 1kHz to 8kHz

d) 2.4GHz wifi will be used

1.5 Summary

There are five chapters in this low-cost vibration monitoring system study, each covering a distinct sort of issue. Each topic shall discuss and include the following titles: Introduction, Literature Review, Methodology, Results and Analysis, Discussion and Conclusion. The following is a full description of the thesis outline for each chapter:

Chapter 1: Introduction. This part of the report will describe the categories of project in general terms. This section will list the objectives of the project. The project'sscopes will also be given in this part of the report.

Chapter 2: Literature Review. This section will explain the preparation of vibration monitoring system in detail. This chapter will provide a more in-depth description of the project title which is supported by previous research. Thissection will build on the theoretical and conceptual ideas of vibration monitoringsystems that have been studied before.

Chapter 3: The methodology of the project is about the overall flow of the entire project. This part will discuss development of a low-cost vibration monitoring system.

Chapter 4: The result and the analysis. This part of the report will explain about the outcomeObtained, as well as the performance of the system.

Chapter 5: Discussion and Conclusion. This chapter will highlight accomplishments, practicalities, and future recommendations. Lastly, the project's conclusion willalso be present in this section.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The theoretical and conceptual ideas relating to the project's title will be reviewed in this area of the report. Previous research, such as books, journals, articles, and magazines, will be used to support all the theoretical and conceptual ideas described in this chapter.

2.2 Vibration

Vibration refers to the oscillating or swinging motion of an object, such as a pendulum or string. In physics, vibration is defined as the continuous rotation of a molecule in an elastic object or substance away from its equilibrium point. The path of the vibrating particle can be straight, spherical, or curved when disrupted, generating tones or carrying melodies through air particles (Biology Online, 2023).

It is common practice to use transducers (acceleration, velocity, or displacement) to obtain vibration data from machines these devices take the raw data from the sensors and transform it into a usable signal, typically a voltage. The frequency of interest is a crucial factor in choosing the measurement parameter for example acceleration, velocity, or displacement. (A.Yunusa et al.2014).

The amplitude and frequency of the vibrations, which can both reveal the severity and origin of the machine problem, can be used to assess the machine's condition .The human brain of qualified individuals combined with the senses of touch and hearing, which serve as a vibration analyser, can initially identify machine issues without the aid of vibration instruments. Data collecting, signal processing, and problem recognition are the three primary phases that commonly make up the vibration analysis for machine monitoring and diagnostics. (Wan Rahiman et al. 2021).

The Fourier conversion of vibration monitoring sensor data produces an amplitude spectrum measurement. Accelerometers are the most popular type of sensor and their output is a frequency-dependent acceleration spectrum. The "flat" frequency response of accelerometers makes them desirable, because random ground noise also tends to have a "flat" acceleration pattern . It is also possible to write amplitude spectra in terms of velocities or positions as a function of frequency. The Fast Fourier Transform (FFT) is commonly used in spectrum analyzers. Input data is analyzed by an FFT device, which then graphs the amplitude of each frequency. Both the magnitude and frequency of any periodic noise sources should be taken into consideration. When analyzing periodic vibration, an amplitude spectrum provides results that are unaffected by the size of the data collection. (Gamma Data, 2020).

By analysing the machine to identify the fault or possible issue, such as imbalance, wear, misalignment, defective bearing, friction whirl, and cracked gear teeth, vibration can be avoided. Numerous diagnostic techniques, including oil analysis, vibration signal analysis, particle analysis, corrosion monitoring, acoustic signal analysis, and wear debris analysis, have been used over time. Acoustic and vibration signal analysis stand out among these analyses as attractive options since numerous defects can be found without the machine being stopped or torn apart. (Wan Rahiman et al. 2021).

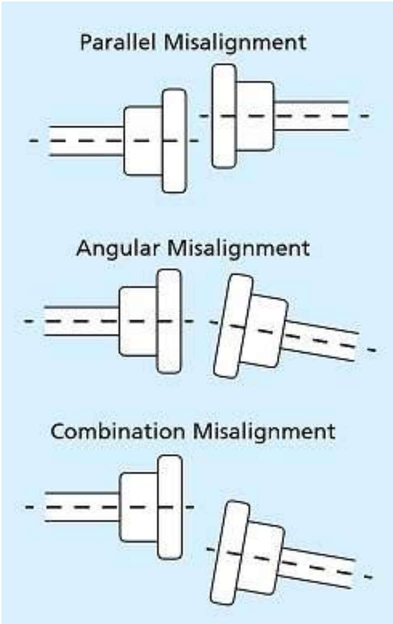

Figure2.1 Types of the alignment problem

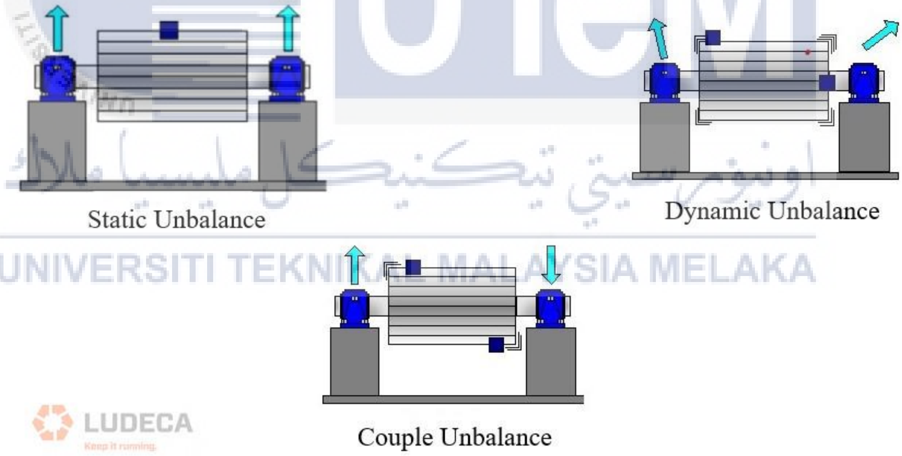

Figure 2.2 Types of the unbalance

Figure 2.3 Types of the bearing damage

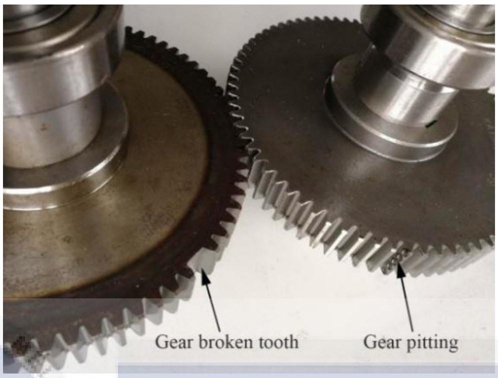

Figure 2.4 Types of the damaged or worn-out gear

2.3 Sensor

Different industries employ sensors for a variety of everyday and commercial applications. Sensor system use in industrial demonstrations has recently increased, showcasing their extraordinary capabilities. In order to track systems and equipment at each location, sensors connect various devices and systems and allow diverse units to communicate. Ordinary sensors have become intelligent sensors thanks to the Internet of Things (IoT), which allows complicated calculations to be made locally in a sensor module from observed data. Due to the enhanced powers of sensors, which allow them to be connected to challenging-to-access and sometimes dangerous items, turning them into high-tech geniuses, sensors have grown remarkably small and portable. Since years, sensors have played a crucial role in manufacturing, but until recently, issues including machine noise, signal degradation, and reaction dynamics were mostly contained. (Mohd Javaid et al. 2021)

2.3.1 Vibration sensor

The rapid development of Intergrated circuit technology and computer technology in recent years provides a good and reliable scientific and technical foundation for the development of sensors, which are at the core of today's cutting-edge testing technology due to their central role in modern industry's move toward a digital and information-oriented focus. An essential aspect of current sensor development is its rapid digital, multipurpose, and intelligent improvements. (Sensor & transducer et al.2014)

Vibration Sensors are a common form of vibration monitoring equipment utilised by facility maintenance teams to gain insight into the performance of equipment. Using vibration sensors and analysing the data from these devices, engineers are able to predict equipment failure. Its measure the amplitude and frequency of the study system vibration. Numerous vibration occurrences have frequencyranges ranging from a few kHz to over 100 kHz. There are some common vibration sensor that usually being used such as capacitive, optical, electromagnetic, and piezoelectric vibration sensors. Vibration sensors are measurement instruments. It detects the vibration or oscillation of any equipment or system. The most common use of vibration sensors is to measure the vibration of rotating equipment and machinery, such as pumps, compressors, and steam turbines, that are basically used in the industry. (Athen Sensor, 2020)

2.3.1.1 Eddy-Current Vibration sensor

Eddy-Current sensors are non-contact instruments that gauge a conductive component's location and/or change in position. Magnetic fields are used to operate these sensors. A probe attached to the sensor produces an alternating current at its tip. The component we are monitoring experiences eddy currents, which are tiny currents produced by the alternating current. The sensor keeps track of how these two magnetic fields interact. The sensor will generate a voltage proportionate to the change in the interaction of the two fields as the field interaction varies. For normal operation when utilising Eddy-Current sensors, the component must be at least three times larger in diameter than the sensor; otherwise, sophisticated calibration would be necessary. (Luke Prielipp et al. 2019)

2.3.1.2 Piezoelectric Vibration Sensor

Piezoelectric sensors are electronic components capable of transforming a mechanical or thermal input into an electrical signal. They are used to quantify regular vibrations as well as various accelerations or speeds. It operates using the electromechanical coupling principle. Some materials generate an electrical voltage when subjected to mechanical stress and vice versa; this phenomenon is known as piezoelectricity. The sensor are used by maintenance specialists to predict machine maintenance. (Althen Sensors. 2020).

Piezoelectric materials have the capacity to deform in response to electrical stimuli or become electrically polarised with the application of external force. In order to realise the SHM employing a range of techniques, sensors based on the piezoelectric effect could be employed as multifunctional sensors. Numerous benefits exist for piezoelectric sensors, including their compact size, light weight, low cost, availability in a range of formats, high sensitivity, and others. They primarily measure force in addition to other characteristics like pressure, acceleration, temperature, and strain by turning the collected data into an electrical charge. They are based on the electromechanical energy conversion principle. (Min Ju et al. 2022).

2.3.1.3 Accelerometer vibration Sensor

A little electromechanical instrument called an accelerometer is used to measure both acceleration and the various forces acting on an object. Accelerometers are capable of measuring both static and moving forces. Gravity and friction are examples of static forces, which maintain an object's uniform direction and position without changing them. the accelerometer using g(m/s2) as the SI unit. Dynamic forces, in contrast, are unpredictable and actually alter an object's direction or location. Because they can detect changes in acceleration and translate them into vibration data, accelerometers are incredibly helpful. Accelerometers use electrical impulses to measure vibration, providing information about the health of a machine. (Everett Jesse et al. 2021)

Triaxial accelerometers have greater memory capacity than uniaxial accelerometers but are significantly more expensive. The accelerometer is a widely utilised sensor due to its dependability, simplicity, and durability. It is divisible into a piezoelectric accelerometer and a microelectromechanical system accelerometer. (Mohd Ghazali et al. 2021).

2.4 Micro-electro-mechanical system (MEMS)

Researchers and developers of MEMS have proven a staggering variety of microsensors over the past few decades for practically every conceivable type of sensing modality, including temperature, pressure, inertial forces, chemical species, magnetic fields, and radiation Surprisingly, many of these micromachined sensors have shown to function better than their macroscale competitors. In other words, a vibration sensor created using the most accurate macroscale level machining techniques typically underperforms a vibration transducer built using micromachining. (mems-exchange, 2021)

Microelectromechanical systems accelerometers are a desirable replacement for Piezoelectric accelerometer in the embedded space due to their tiny size, low cost, and low power consumption. MEMS accelerometers have undergone extensive study and development in preparation for usage in widely distributed handheld gadgets like smart watches, tablets, and smartphones. In addition to significantly reducing size and unit costs, this innovation has also speed up the development of MEMS accelerometers with improved precision and bandwidth. (ivene koene et al.2020).

Due to their compact design, MEMS accelerometers can be easily attached to a wide range of objects without interfering with their mechanical operation. Furthermore, using a MEMS accelerometer for data collection required fewer parts than systems based on Piezoelectric accelerometers. Most of modern MEMS accelerometers communicate with inexpensive microcontrollers through a serial data channel. In addition, MEMS accelerometers may often record acceleration data along multiple axes together, allowing for the capture of movement in all three dimensions. Impact measurement, vehicle monitoring, the study of vibration in spinning equipment, and gesture and motion tracking are just some of the measurement systems that have made use of MEMS accelerometers. (Ivene koene et al. 2020).

MEMS can be considered as a more advanced version of conventional integrated circuit fabrication. The primary difference between MEMS and conventional intergrated circuit Manufacturing technology is that MEMS can construct mechanical components such as gears, springs, and beams in addition to electrical components like as capacitors and inductors. Only conventional intergrated circuit technology can produce conductors, insulators, diodes, and transistors (Administrator Electronics Hub, 2019).

2.4.1 MEMS Sensor

In basic terms, a sensor is an apparatus with fundamental detecting components that detect physical quantities like temperature or humidity and transform them into electrical signals. An amplifier, filter, or a combination of these components are also included in a sensor's signal processing section.

Devices referred to as microelectromechanical systems (MEMS) are characterised by their tiny size and manufacturing process. These are composed of parts with sizes ranging in between 1 to 100 micrometres. MEMS devices come in a variety of levels of complexity, from straightforward designs to multi-moving element electromechanical systems that are combined with microelectronics. MEMS is a general term for mechanical microstructures, micro actuators, microsensors, and microelectronics (electronicsforu.com, 2018).

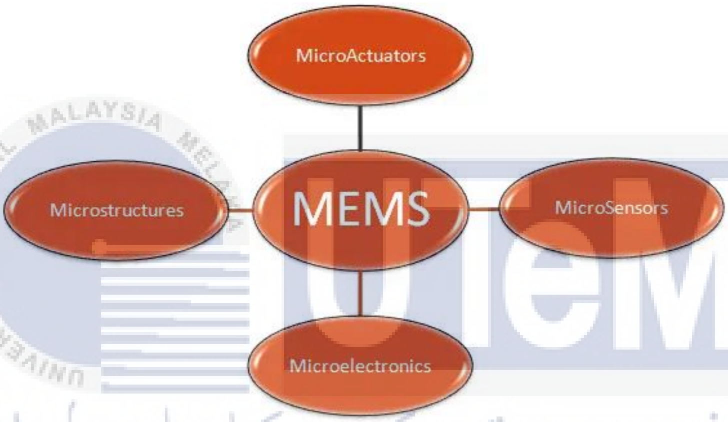

Figure 2.5 General block diagram of MEMS device

A MEMS sensor that has been created and constructed utilising MEMS technology is known as a microfabricated microsensor, or simply a MEMS sensor. The MPU6050 integrated circuit, for instance, contains a digital mobility processor, a 3-axis gyroscope, and three-axis accelerometers. It is manufactured using MEMS technology (Electronic forum, 2018).

MEMS sensors are a key component in the creation of smart sensing systems because they offer significant additional benefits such downsizing, low cost, and low power consumption. A subject called microsystems develops systems at the smallest possible scale. It examines materials and methods for creating incredibly tiny systems and devices with characteristics and behaviours similar to those of existing macrosystems.

A few benefits are low power consumption, small size, and cost-effectiveness related to array production possibilities. Other advantages of MEMS are its light weight, high resolution, consistent performance, and simplicity of software and equipment interaction. Inertial sensors, chemical sensors, satellites, pressure sensors, accelerometers, and military applications are only a few examples of devices where micromechanical-to-micromechanical device efficiencies have increased. Additionally, for commercial manufacturing, the inexpensiveness and simplicity of the forming procedure are essential (Springerlink, 2021).

2.4.2 MEMS Accelerometer

Moveable proof masses with plates attached to the frame by a mechanical suspension system make up a MEMS accelerometer. The proof mass tends to obstruct forward motion when accelerated due to its inherent inertia. As a result, the force produced by the applied acceleration is equal to the applied acceleration. For sensing low-frequency vibration and acceleration, MEMS accelerometers are the ideal choice. It is more sensitive in addition to being more effective. Up to many tens of kHz, modern MEMS accelerometers provide high data quality. Its low signal-to-noise ratio is a significant drawback. (Rahiman and Mohd Ghazali, 2021)

Building tiny structures by fusing mechanical and electrical elements is known as a microelectromechanical system (MEMS). Costs are reduced by miniaturisation since less material is used. Furthermore, MEMS may be employed in spaces where a conventional system would not fit since they are compact and lightweight. Applications for MEMS accelerometers range from vibration monitoring to tilt control to shock detection. Due to its compact size, light weight, and built-in signal filtering, MEMS accelerometers are unique. For instance, integrated a whole wireless data collection system that consists of a MEMS accelerometer, a CPU, and an RF transceiver. They discovered that it only weighs a small amount overall. (Marcocchio 2018).

2.4.3 MEMS Gyroscope

Gyroscopes are a crucial component of navigation systems because they can give carriers precise navigation positioning and attitude parameters. Their accuracy and dependability are crucial to navigation systems because they are used in many aspects of spaceflight, aviation, and navigation. Measurement and control systems are getting more and more complicated as current technology advances, which makes them harder to debug and increases the likelihood that they will fail. To enhance the gyroscope's precision and dependability, quickly giving the carrier with navigation and positioning parameters, and seeing, identifying, and foreseeing navigation system flaws. (Rang Cui et al. 2023)

In order to enable sophisticated algorithms like sensor fusion (for orientation estimation in 3D space), 3-axis gyroscopes record angular rate and are typically paired with an accelerometer in a common package. The primary function of a gyroscope in inertial space is to measure angular velocity. The output of the gyroscope, however, exhibits some random noise and drift as a result of semiconductor thermal noise and electromagnetic interference, which affects the accuracy of the measured angular velocity signal and compromises the stability of the entire system. In order to minimize noise and account for the MEMS (Micro Electromechanical System) gyroscope's movement while in use. (Hui guo et al. 2019).

2.4.4 Wireless MEMS Sensor

A low-power wireless sensor network can be integrated with a wireless communication protocol that can be used by the subject to take long-term ambulatory measurements while engaging in activities like walking, climbing stairs, exercising, etc.

thanks to advancements in MEMS sensor technology. 'Bluetooth' and 'Wi-Fi' (802.11x) are the most popular wireless data transfer technologies in personal area networks. Numerous applications combine wireless communication with small, low-power MEMS sensors. This makes it possible to deploy in challenging environments and remote sites where installing cable access would be too difficult or expensive. Due to minimal downtime, installing wireless sensors takes less time than installing wired ones, which saves money. Troubleshooting is expedited by improved installation. (Neelesh K. et al.2019)

Effective troubleshooting is advantageous when a machine behaves unexpectedly, and the cause cannot be identified using the mounted sensors. In addition to measuring the static components of the machinery, sensors can also be employed to measure the moving components. This type of sensor setup has been used to investigate the behaviour of spinning shafts and wind turbine blades. In these environments, measurement frequently necessitates wireless data transfer and battery-powered sensor nodes (Koene et al., 2020).

2.5 MPU 6050

The MPU-6050 components are the first Motion Tracking devices created for smartphones, tablets, and wearable sensors that are low power, low cost, and high performance. (INVEN SENSES 2023). The MPU6050 is the first and only 6-axis motion tracking system in the world. It was created for wearable sensors, smartphones, and tablets that require less power, little money, and a high level of performance. Three axes of acceleration and rotation, a three-axis gyroscope, and 16-bit Analog to Digital Converter conversion for each channel make up the MPU6050's key characteristics. (LASTMINUTE ENGINEERING, 2023).

The MPU-6050 devices incorporate a 3-axis gyroscope and a 3-axis accelerometer on the same silicon die, as well as a Digital Motion Processor that processes complex 6-axis Motion Fusion algorithms. Through an auxiliary master I2C interface, the device can access external magnetometers or other sensors, allowing the devices to collect a complete set of sensor data without the intervention of the system processor. (INVEN SENSES 2023).

Optionally, additional IIC modules, such as a magnetometer, can be interfaced via the module's numerous output pins. Due to the configurable IIC address of this module, the AD0 pin may be required to connect multiple MPU6050 sensors to a Microcontroller. This module includes well-documented and up-to-date libraries, making it simple to use on popular platforms like Arduino. If you require an accelerometer for your RC vehicle, drone, personality robot, humanoid, biped, or anything similar, this sensor may be a suitable fit (COMPONENTS101, 2021).

The MPU6050 integrated circuit is affixed on the GY-521 inertial sensor, which is small and lightweight (approximately 18 grams). The devices are offered in a 4 mm x 4 mm x 0.9 mm. The output frequency of the MPU6050 accelerometer is fixed at 1kHz, resulting in a bandwidth of 500Hz. The sampling rate of the system, however, can be adjusted between 4Hz and 1kHz (MCU) by adjusting the delay time at the microcontroller unit. The MPU-6050 abstracts motion-based complexities, offloads sensor management from the operating system, and offers a structured set of application programming interfaces (APIs).The parts feature a user-programmable gyro full-scale range of 250, 500, 1000, and 2000 °/sec (dps) and a user-programmable accelerometer full-scale range of 2g, 4g, 8g, and 16g for precise tracking of both rapid and slow motions. In addition to an embedded temperature sensor and an on-chip oscillator with 1% variation over the operating temperature range, the semiconductor also includes a temperature sensor. (INVEN SENSE, 2023).

Part #	Gyro Full Scale Range	Gyro Sensitivity	Gyro Rate Noise	Accel Full Scale Range	Accel Sensitivity	Digital Output	Logic Supply Voltage	Operating Voltage Supply	Package Size
UNITS:	(°/sec)	(LSB/°/sec)	mdps/rtHz	(g)	LSB/g		(V)	(V)	(mm)
 MPU-6050	±250 ±500 ±1000 ±2000	131 65.5 32.8 16.4	0.005 0.005 0.005 0.005	±2 ±4 ±8 ±16	16384 8192 4096 2048	I²C	1.8V±5% or VDD	2.375V–3.46V	4x4x0.9

Figure 2.6 Product Detail for MPU6050 (Source from: https://invensense.tdk.com/products/motion-tracking/6-axis/mpu-6050/)

2.6 Hibiscus sense ESP32

The ESP32, created by Espressif Systems, is a popular system-on-chip (SoC) microcontroller. Wireless communication, Internet of Things (IoT) devices, home automation, robotics, embedded systems, and much more can all benefit from this low-cost, extremely flexible microcontroller. (AumRaj et al. 2023)

When developing Internet of Things (IoT) applications, the ESP32 makes it simple to employ the Arduino IDE and the Arduino Wire Language. For a wide range of uses, the ESp32 IoT Module integrates Wi-Fi, Bluetooth, and Bluetooth. This module has 2 independently programmable CPU cores, each with its own power supply and a clock speed that can be set between 80 and 240 megahertz. All ncd.io IoT products are compatible with this ESP32 IoT Wi-Fi BLE Module with Integrated USB. (Manish Jugran et al. 2023).

Because of its low power consumption, the ESP32 is suitable for low-power and energy-saving uses. The development of the ESP32 is backed by a sizable community of programmers and enthusiasts. Furthermore, a wide variety of development boards, software libraries, and tools are at your disposal for creating and debugging programs. (AumRaj et al. 2023).

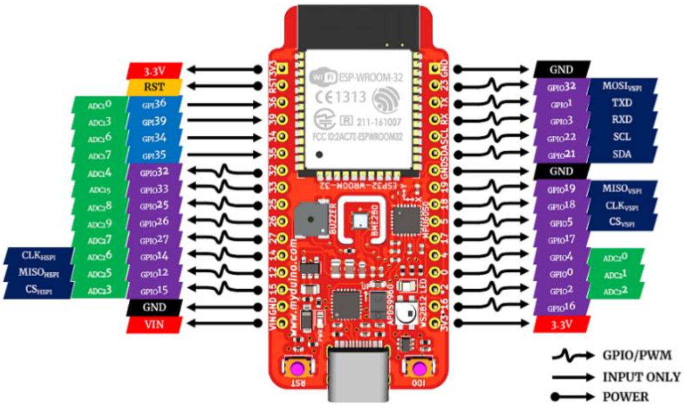

Figure 2.7 Product Detail for ESP32 (https://my.cytron.io/p-hibiscus-sense-esp32-iot-development-board)

2.7 Arduino IDE software

Arduino is a microcontroller that can be quickly and easily reprogrammed, deleted, and rewritten because of its open-source nature. The Arduino platform was released in 2005 with the intention of making it simple and cheap for makers of all stripes to build gadgets with built-in sensors and actuators. This open-source computing platform is built on inexpensive microcontroller chips and may be used to create and program all sorts of electronic gadgets. Like other microcontrollers, it can accept inputs and regulate the outputs of many electronic devices, allowing it to function as a miniature computer. (leo et al. 2016)

Open-source and free software known as the Arduino IDE. The IDE means, Integrated Development Environment. It is used to program Arduino boards. The IDE program works fine on Windows, Mac OS X, and Linux, among others. It's compatible with the C and C++ programming languages, these 8- or 32-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors may be readily programmed. (Java Point 2023).

Figure 2.8 Arduino interface with ESP32 (https://lastminuteengineers.com/esp32-arduino-ide-tutorial/)

2.8 Blynk IoT application

Blynk was created with IoT in mind. It has the ability to remotely manage hardware, display sensor data, store information, and present it in a graphical format. Blynk is an Internet-of-Things (IoT) platform that enables iOS and Android smartphones to remotely manage IoT devices like Arduino, Raspberry Pi, and NodeMCU. The accessible widgets are compiled, and the program then supplies the correct address, resulting in a graphical user interface (GUI) or human-machine interface (HMI). (Syufrijal et al. 2019).

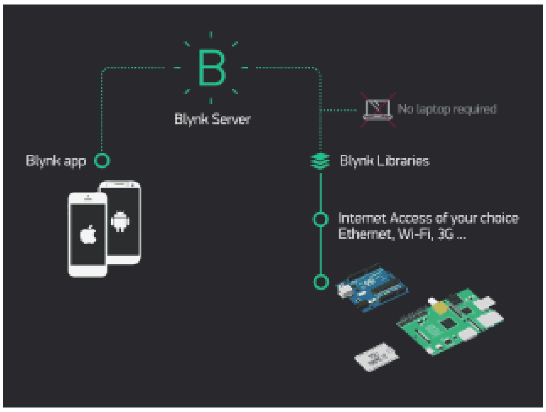

Figure 2.9 Blynk IOT interface (https://iotdunia.com/blynk-iot/)

2.9 Vibration Monitoring System / Vibration Analysis

Typically, wireless vibration monitoring is a component of a preventive maintenance strategy. With wireless vibration monitoring, maintenance crews install Industrial Internet of Things (IoT) sensors on critical machinery to collect vibration measurements over time and detect issues. Depending on its capabilities, a vibration sensor may detect, analyse, and even diagnose machine defects. (PRUFTECHNIK,2022)

Vibration analysis is the process of keeping track of deviations from a system's predetermined vibration signature and searching for anomalies. Any moving object will vibrate, and these vibrations will vary in amplitude, intensity, and frequency. It is possible to use vibration data to acquire insights on the health of equipment since these vibration characteristics can be connected to physical processes. (DYNAPAR, 2019)

The primary vibrational properties are amplitude, frequency, phase, shape, and, when a proximity sensor is used, position. When referring to a vibration's amplitude, we mean how strong it is. A vibration's source can be located using frequency. Another sign of a problem is a change in vibration frequency that is unrelated to a change in machine speed. Frequency awareness helps to swiftly locate specific issues. Finding the vibration's time and location is made easier with the help of phase. The different amplitudes and frequencies of a specific vibration, when observed in the waveform, can disclose a considerable deal of information about the machine in question. The amplitude recorded by a vibration monitoring system can reveal variances in motions from the time the machine starts to the precise instant when a part may have a problem or issue. (Everett jesse et al. 2023)

Vibration monitoring involves gathering data, putting it together, and coming to important conclusions. The gearbox's fitted accelerometer is utilised to collect vibration data. Waveform and vibration data are both susceptible to time-domain, frequency-domain, and time-frequency analysis. In time domain analysis, statistical features are taken from the data to describe the nature of the vibration signal. In a time-domain analysis, statistical parameters are retrieved to explain the characteristics of the time waveform, such as mean, peak value, standard deviation, crest factor, and root mean square. (Praveenkumar et al., 2018).

The time waveform (oscillation amplitude as a function of time) of vibration along the axis of interest is the outcome. The time waveform is converted into a vibration frequency spectrum using a Fast-Fourier Transform (FFT) technique. The frequency spectrum's scope is determined by the accelerometers and the analogue-to-digital converter (ADC) utilised. As previously stated, most of the insight provided by vibration analysis is dependent on matching frequency spikes to physical system parameters. (DYNAPAR, 2023).

2.9.1 Low- Cost Vibration Monitoring System

One of the pillars of Industry 4.0 is condition monitoring. In industrial plants, many methods have been created to monitor current, pressure, temperature, and other factors. With advancements in microelectromechanical systems, it is now possible to deploy a plethora of low-cost sensors capable of sensing, calculating, and wirelessly transmitting to gather information for environmental and equipment monitoring. Wireless sensor networks are used to connect these sensors. Using IoT protocols and technologies, they send data to the cloud for storage or additional analysis. Many public cloud service providers provide IoT services that use common protocols for real-time data storage and analytics. This enables the use of historical data to forecast future equipment failures. (Magadan L. et al. 2022)

Additional research revealed that the MPU 6050 (MEMS accelerometer) had been employed in the creation of low-cost vibration monitoring systems, such as those used to check vibration on operating CNC milling machines in a limited number of places (INVEN SENSE, 2022). In earlier research, showed the MPU6050's accuracy for vibration analysis by contrasting its output with that of a piezoelectric accelerometer (an industrial vibration sensor). The response of the MPU6050 is more predictable when these sensors are subjected to the same mechanical stimulus. The MPU6050 rectification error's qualitative and quantitative behaviour was similar with how it had been previously reported in this study. (IVEN SENSE 2022).

2.9.2 Wireless Vibration Monitoring System

An accelerometer with the ability to measure vibration and transmit it to a receiver through a wireless protocol make up a wireless vibration sensor. Some of these sensors might even communicate data in real time, depending on the wireless protocol being used. Having the capacity to connect through a mesh network or peer-to-peer technology. Online Condition Monitoring is the most significant use for wireless vibration sensors in today's world. A wide range of wireless protocols enable the replacement of current wired solutions with wireless accelerometers in several applications. The Bluetooth 5.0 mesh network technology makes it simple to create extensive sensor networks. (ER BESSD, 2022).

Micro-Electro-Mechanical Systems (MEMS) make the future of wireless sensor networks extremely promising and open the door to many practical applications, ranging from home appliances to sophisticated industrial equipment. According to researchers, the embedded systems market for WSN application will grow at a rate of 50% per year. Due to its appealing characteristics, including low cost, built-in intelligence, ease of installation, flexible networking, and low energy consumption, wireless sensor networks is currently growing its use in condition monitoring domains. (Ould zimirli et al. 2022).

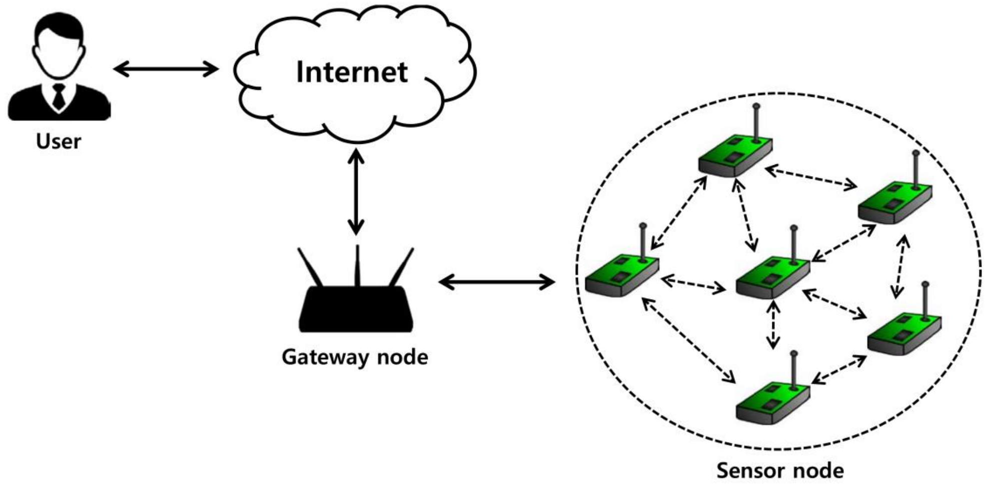

Figure 2.10 Wireless Sensor Network

(Source from: https://www.mdpi.com/1424-8220/20/15/4143)

CHAPTER 3

METHODOLOGY

3.1 Introduction

For this chapter will be proposed for the solution for the objectives to be met. This chapter will explain all the workflow for this project and all the hardware and software that are going to be used in this low-cost vibration monitoring system project. The Hibiscus sensor ESP32, MPU6050 sensor, Blynk IOT software and Arduino IDE were used in the project to create a low-cost vibration monitoring software solution. To gather, analyse, and monitor data remotely, a software was being used. Moreover, in this chapter, will go through about vibration monitoring system software and hardware integration.

3.2 Method Workflow

Important to this investigation is a sensor that converts the acceleration of a moving object into an analogue voltage signal. Once the acceleration in a given dimension is known, the velocity and displacement may be calculated with a simple integration or double integration of the acceleration with respect to time.

The software will open an interface port in order to receive data from a data acquisition device. Incoming data is analysed by software, which then converts values in 2D (amplitude - time) to a visual representation of the signal's vibration. Each time fresh information enters the port, the graphics object is refreshed to provide a more streamlined set of real-time visualisation possibilities.

3.3 Project Flow Chart

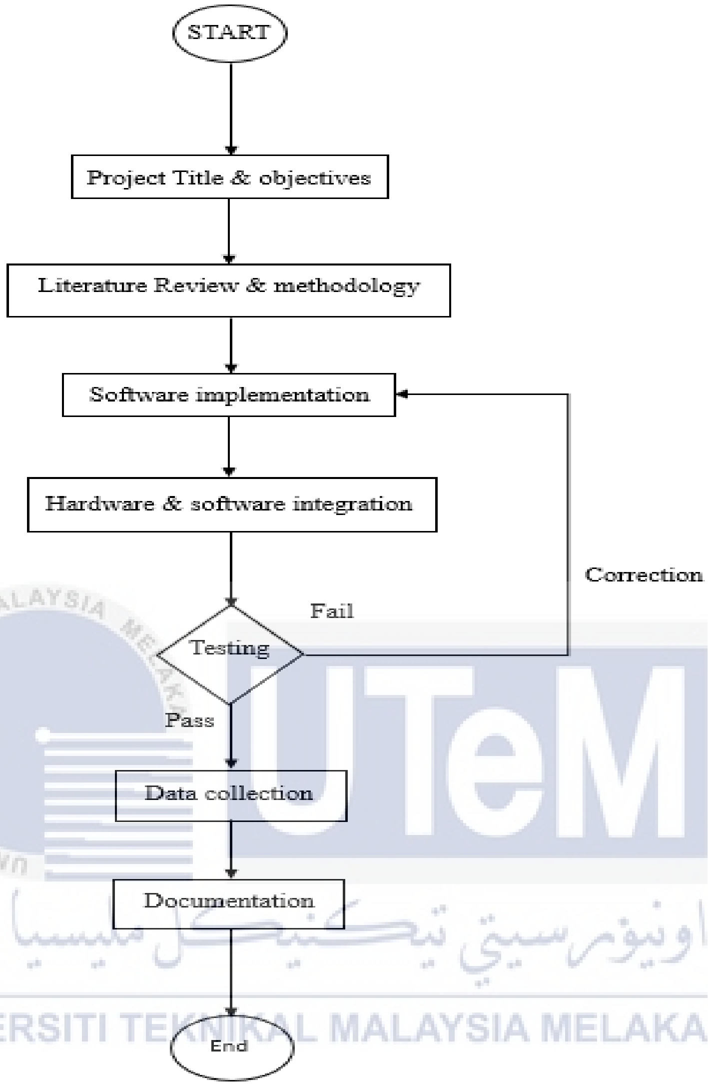

Figure 3.1 Figure 3.1: Project Workflow Flowchart

3.4 Vibration Monitoring System

The development of both the hardware and the software are important aspects of the vibration monitoring system, and both of these should be taken into consideration. The software component focuses more on the programming selection that was used to programme the vibration monitoring system, while the hardware component focuses more on the component selection and the physical appearance of the component itself. The hardware portion of this project is mostly focused on the selection of essential components and their real appearance in section **3.5**, while section **3.6** discusses the software development.

3.5 Hardware That Being Used

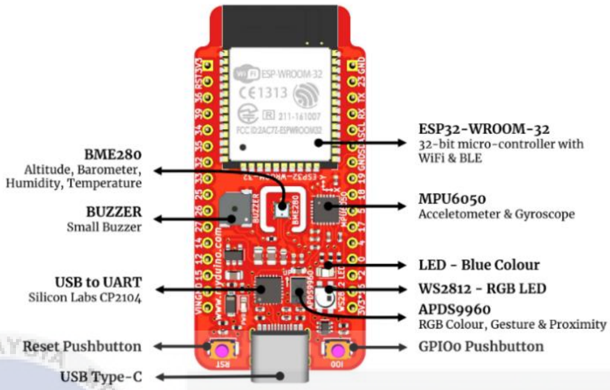

Figure 3.2 Overview of Hibiscus Sense (Source from: https://github.com/myinvent/hibiscus-sense-arduino/wiki/01.-Introduction-to-Hibiscus-Sense)

Working Voltage	3.3V
Working Frequency	240MHz
MPU6050's Sampling Range(Max)	1kHz to 8kHz
MPU6050's Temperature	-40°C to 85°C
Dimension	58.7mm X 27mm X 20.4mm (Length X Width X Height)

Table 3.1 Hibiscus Sense required specification

The Hibiscus Sense is a development board that, connect by using Wi-Fi and Bluetooth, enables wireless connectivity with a computer or smartphone. As a result, for this project the Hibiscus Sense use a power bank in order to function as its source of electrical power. Just connect the power bank, using a cable with a Type-C end, to the USB port located on the hibiscus sense. This will let the power bank to act as the power supply and deliver the required current and voltage to the development board.

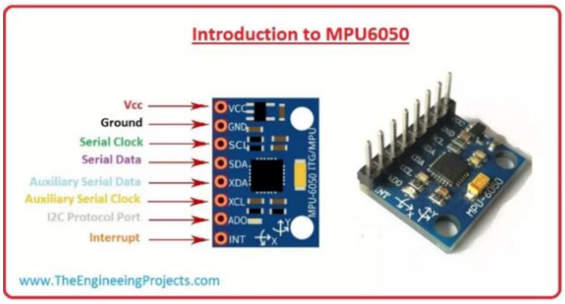

Figure 3.3 GY-521 MPU6050 Accelerometer Sense (Source from: https://www.theengineeringprojects.com/2019/02/introduction-to-mpu6050.html)

Operating Voltage & Current	3.3V to 5V, 500µA
Operating Frequency	20MHz
Sampling Range	1kHz to 8kHz
Temperature Sampling Range	-40°C to 85°C
Dimension (Excluding Pins)	21.2 × 16.4 × 3.3mm

Table 3.2 GY-521 MPU6050 Accelerometer specification

The GY-521 MPU6050 sensor module, also called MPU6050, is used to monitor and assess machine vibration while it is in operation. It can measure linear acceleration and rotational motion thanks to its three-axis accelerometer and three-axis gyroscope. It is possible to gain important insights about the machinery's health and condition by tracking and examining the vibration signals it produces. To find potential problems and deviations, the data from the MPU6050 sensor module can be compared to reference data or recognised vibration patterns. This makes it possible to do preventative maintenance, reducing downtime and improving machinery performance. For effective vibration analysis and assuring the dependable operation of industrial machinery, the MPU6050 module is a crucial tool.

Figure 3.4 Power Bank with 5000mAh

For this project, a 5000 mAh power bank was selected to serve as the Hibiscus Sense's and GY-521 MPU6050 power source. In addition to being small and lighter than other power banks, this one's 5000 mAh capacity is sufficient for power generation and hibiscus support. Just connect the power bank using a Type-C cable to the USB port on the hibiscus sense to utilise it as the power source for the GY-521 MPU6050 and Hibiscus Sense.

Figure 3.5 Jumper wire

These are male-to-male, female-to-female, and male-to-female jumpers, respectively. You can use these to traverse the gap between female headers on any Circuit. A 2.54mm header will fit multiple adjoining jumpers. Details of the Specs Dupont single-contact male/male/female (M/M/F) connectors. There is a 2.54mm Pitch. You can have a jumper that's 20cm or 30cm long. And the total number of possibilities is 40 ways.

Figure 3.6 Type c extension cable

Usb Type	Usb 3.1 gen2 male to female
Base Adapter	Data cable station nintendo
Power	100w support
Voltage	20V/5A
Speed rate	10Gbps

Table 3.3 Type c extansion cable specification

This usb type C extension cable being used to connect the hibiscus sense ESP32 to the 5000mah power bank as a power supply.

3.6 Software that Being Used

The focus of this subtitle is to provide an explanation of the interface software that are utilised in order to build the real-time time domain graph by utilising the data that was obtained for the purpose of vibration analysis. The Arduino IDE software version 1.8.19 was selected for this project because it is free to use, simple to gain access to, and, most importantly, the development board of the ESP32 microcontroller is compatible with this programming software. These are the three reasons why the Arduino IDE software version 1.8.19 was selected. The Arduino IDE is a piece of software that may be used to programme the coding for this vibration monitoring device. In addition, the programming code for Arduino is written in Java and is based on the C++ programming language.

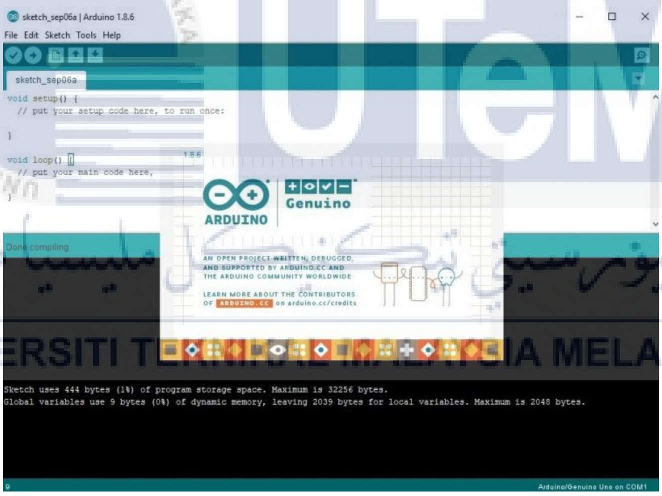

Figure 3.7 Arduino IDE software

The second software used for interfacing is Blynk software, which was selected for its ease of accessibility and free usage for displaying data. Blynk software provides the capability to monitor the vibration data on both the Blynk IoT website and the Blynk mobile app. By receiving the data from the microcontroller of the Hibiscus Sense system through Wi-Fi, the Blynk software allows users to visualize the vibration data in the form of gauge charts and graphical representations. This feature enables users to easily interpret and analyse the vibration information, facilitating effective monitoring and analysis of the system's vibration characteristics. The utilization of Blynk software enhances the user experience by providing convenient and comprehensive access to the vibration data.

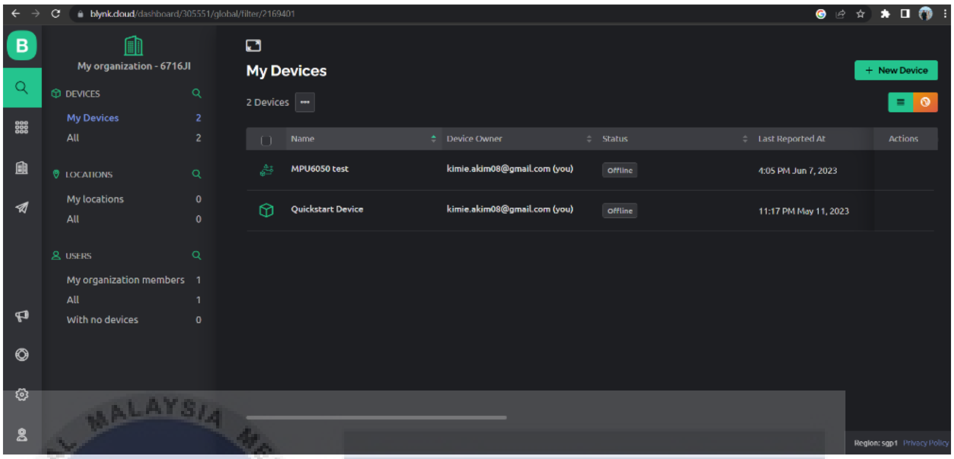

Figure 3.8 Blynk software (Website and Moblie App)

Figure 3.9 Gauge Chart on Blynk software

3.7 Analysis Cost

In this subtopic will make analysis of calculating the cost of building a low-cost vibration sensor and will show some comparison. It involves considering costs for things like supplies, machinery, labour, and other important cost. Analysis cost is the best way to ensure that are our project are not over the limit.

3.7.1 Real Cost

No	COMPONENT	QUANTITY	PRICE
1	**Hibiscus sense ESP32**	1	RM 120.00
2	**USB Type C to Type C (male to female)**	1	RM 10.00
3	**Mini capsule Power bank**	1	RM 30.00
4	**MPU6050 Sensor vibration**	2	RM30.00
5	**Black box project case**	1	RM5.00
6	**Jumper wire (20cm and 30cm)**	2	RM5.00
	TOTAL COST		**RM 200.00**

Table 3.4 Real cost table

3.7.2 Intangible Cost

Costs that are intangible are those that are difficult to quantify or value financially. As a result, non-physical features are linked to intangible costs. As a result for this low-cost vibration monitoring system, the arduino ide software and the Blynk iot applications is considered as a intangible cost.

Figure 3.10 Arduino IDE and Blynk iot applications logo

3.7.3 Comparison cost

In this subtopic we will compare the possible equipment that can be used to built the low-cost vibration monitroing sensor. All the sensor that are be choosen are able to access with the Arduino IDE software for coding.

No.	Required Equipment	Overall Cost (RM)
1.	SW-420 vibration sensor, GY-521 MPU6050, micro-USB data cable, Jumper Wires, ESP32 Devkit V1	5.00 + 12.00 + 7.50 + 3.00 + 35.00 = 62.50
2.	GY-61 ADXL335, GY-521 MPU6050, micro USB data cable, Jumper Wires, ESP32 Devkit V1	18.60 + 12.00 + 7.50 + 3.00 + 35.00 = 76.10
3.	2 x GY-521 MPU6050, micro-USB data cable, Jumper wires, ESP32 Devkit V1	2 x 12.00 +7.50+3.00 + 35.00 = 69.50
4.	Hibiscus Sense – ESP32 Development Board (with USB Type C cable), 2 x GY-521 MPU6050,Jumper Wires	2 x 15.00 +120.00 + 10.00= 165.00

Table 3.5 Comparison Of Low-Cost Vibration Monitoring System Cost

3.8 Summary

In this chapter, it will see a summary that shows the setting for coding in the Arduino IDE as well as the setup for the Blynk IoT application in the picture below. And finally, the final segment will focus on demonstrating how to configure the machine's hardware..

sketch_may10a | Arduino 1.8.19

File Edit Sketch Tools Help

sketch_may10a

```
#define BLYNK_TEMPLATE_ID "TMPL66Fu0D6T9"
#define BLYNK_DEVICE_NAME "MPU6050 test"
#define BLYNK_AUTH_TOKEN "MShwNsHHb381SPJQG4TEShIWBIoWOdPp"
#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "iPhone (2)";
char pass[] = "12345678";

#include <Adafruit_MPU6050.h>

Adafruit_MPU6050 mpu;
Adafruit_MPU6050 mpu1;

void setup(void) {
  Blynk.begin(auth, ssid, pass);
  mpu.begin(0x68);
  mpu1.begin(0x69);
}

void loop() {
  Blynk.run();
  Getmpu();
  Getmpu1();
  delay(2000);
}

void Getmpu(){

  sensors_event_t a, g, temp;
  mpu.getEvent(&a, &g, &temp);
```

Figure 3.11 Arduino IDE Programming Setup

From the **Figure 3.11** it shows the coding in the Arduino IDE software. It will be upload to the Hibiscus sense ESP32 board controller by using the type-C cable. The use of the code is to give a command to the MPU6050 in the Hibiscus sense and then it will transfer the data to the external MPU6050 and by connection to the Wi-Fi it will transmit the data in the Blynk IOT application.

sketch_may10a | Arduino 1.8.19

File Edit Sketch Tools Help

sketch_may10a

```
#define BLYNK_TEMPLATE_ID "TMPL66Fu0D6T9"
#define BLYNK_DEVICE_NAME "MPU6050 test"
#define BLYNK_AUTH_TOKEN "MShwNsHHb381SPJQG4TEShIWBIoWOdPp"
#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "iPhone (2)";
char pass[] = "12345678";
```

Figure 3.12 Arduino IDE Coding Setup to link with the Blynk application.

This are the coding in the Arduino IDE that are be used to give a command to connect with the Blynk IOT application to produce the vibration data from the vibration device.

```
void loop() {
  Blynk.run();
  Getmpu();
  Getmpu1();
  delay(2000);
}

void Getmpu(){

  sensors_event_t a, g, temp;
  mpu.getEvent(&a, &g, &temp);

  Blynk.virtualWrite(V0,a.acceleration.x);
  Blynk.virtualWrite(V1,a.acceleration.y);
  Blynk.virtualWrite(V2,a.acceleration.z);
  //Blynk.virtualWrite(V6,temp.temperature);
}
```

Figure 3.13 Arduino IDE Coding Setup for the MPU6050 built in the ESP32.

```
void Getmpu1(){

  sensors_event_t a, g, temp;
  mpu1.getEvent(&a, &g, &temp);

  Blynk.virtualWrite(V3,a.acceleration.x);
  Blynk.virtualWrite(V4,a.acceleration.y);
  Blynk.virtualWrite(V5,a.acceleration.z);
  //Blynk.virtualWrite(V7,temp.temperature);
}
```


Figure 3.14 Arduino IDE Coding Setup for the external MPU6050

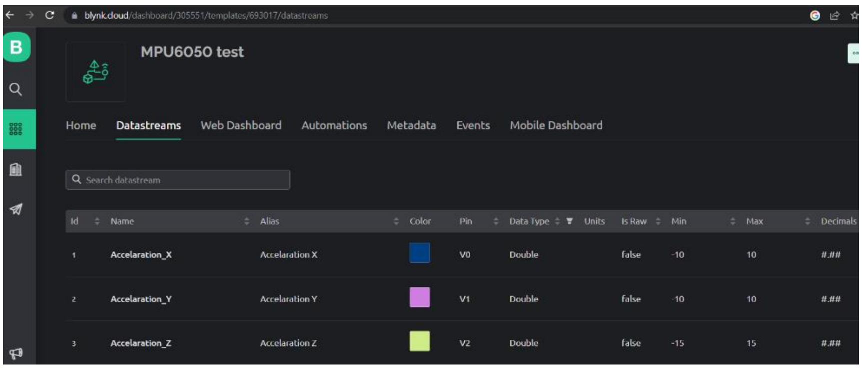

Figure 3.15 The data streams setting for the ESP32 gauge in Blynk.

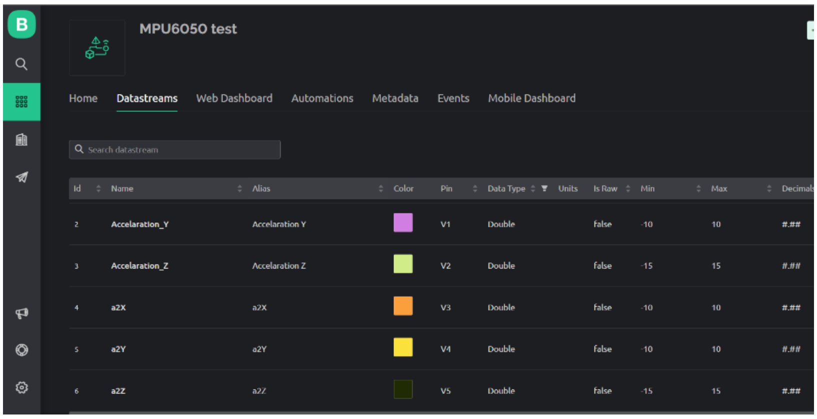

Figure 3.16 The data streams setting for the MPU6050 gauge in Blynk.

For the **Figure 3.15** and **Figure 3.16**, it shows the data streams that have to be setting in the Blynk IOT application so that it will show the data in meter gauge in this application.

Figure 3.17 The meter gauge that will show the reading of the vibration.

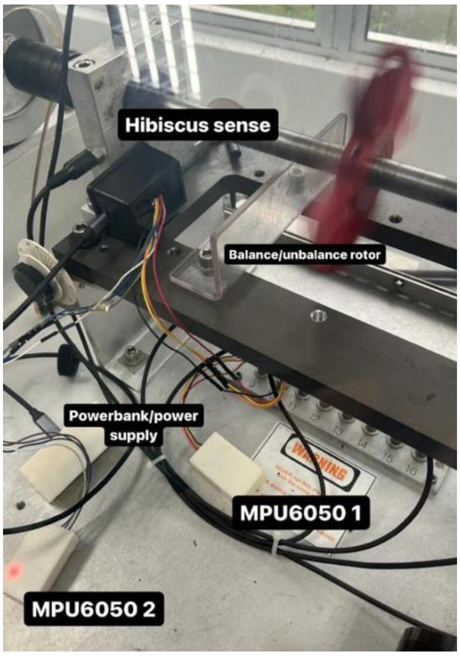

Figure 3.18 Hardware Setup on the Machinery Fault Simulator

In **Figure 3.18**, is showing on how the hardware setup on the machinery fault simulator. the power bank is use as the power generator to the hibiscus sense ESP32 and the MPU6050. The hibiscus sense is installed in the black box with the double-sided tape stick in the bottom of it so that it can stick to the equipment that we are going to monitor. The external MPU6050 is connected to the hibiscus sense with a jumper wire. The machinery fault simulator vibration is used to simulate the vibration based on the bearing that been used.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter exhibits the validation and analysis on vibration monitoring systems for machinery. The results of this section will be displayed in the and graph that are generated from the result of the analysis that received by the Hibiscus Sense ESP32 and the two MPU6050 that are being shown in **Figure 4.1**. The result will be compared with the data that we get from the actual vibration meter as shown in **Figure 4.2**. This section will present the validation of the result and finding from the Low-cost vibration monitoring system and the actual vibration meter that are we using in the lab that the university provide.

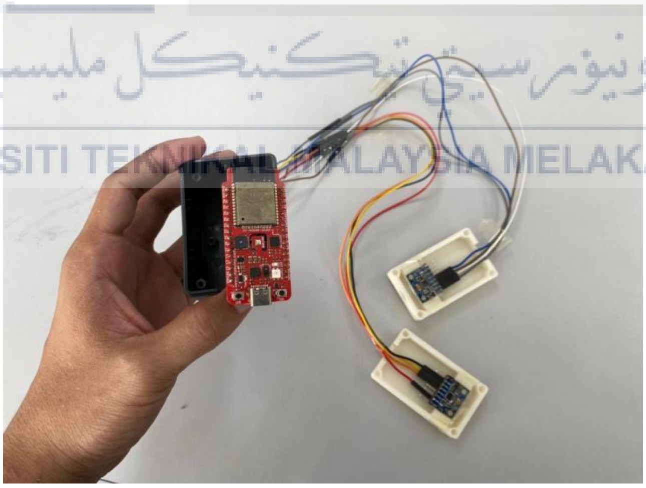

Figure 4.1 Hibiscus sense ESP32 and two MPU6050

Figure 4.2 Vibration meter

4.2 Data comparison and data collection

For the purposes of data comparison and vibration analysis, this section displays the data of vibration that has been collected during the vibration monitoring on the computerized vibration trainer that are shown on **Figure 4.3** in table and graphical form. The three MPU6050s' acquired data are all expressed in m/s2, the unit of acceleration. Since the temperature data is not being used to determine the vibration monitoring system's ambient temperature while data is being recorded, it will not be used for data acquisition or comparison. The actual vibration meter as shown in **Figure 4.2** can generate the maximum and minimum data get at every run. So for this data comparison the data that are being used is the maximum and the minimum data that shows on the actual vibration meter. The data comparison will be shown in tabular and graph.

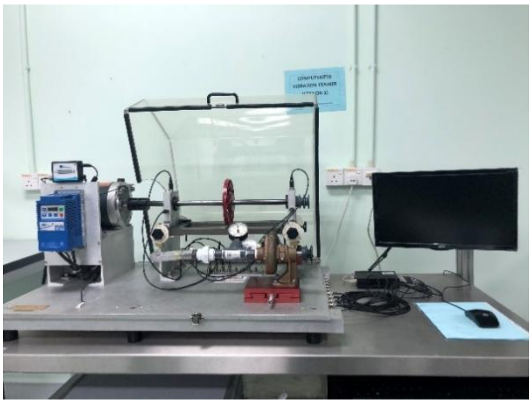

Figure 4.3 Computerized vibratraion trainer

4.2.1 Under balanced condition

As seen in **Figure 4.4**, when the rotor is free of bolts and nuts, the machinery fault simulator generates balanced conditions. For this vibration monitoring we are using three different speeds, the motor speed was set to 10 RPM, 20 RPM, and 30 RPM, respectively, data was gathered. The data that is generated from the Blynk software is shown on the computer's screen and it being recorded for data validation purposes. As seen in **Figure 4.5,** the dashboard of the Blynk software shows the data from the low-cost vibration monitoring system. It is being used to compare the data that is generated from the actual vibration meter that is being used in the lab for study purposes. As shown in **Figures 4.6**, the minimum, and the maximum data that the actual vibration meter generates from the test.

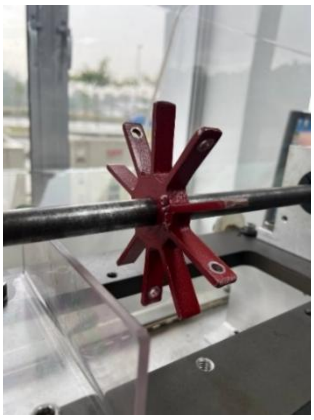

Figure 4.4 Rotor with no bolts and nuts

Figure 4.5 Display data in Blynk software

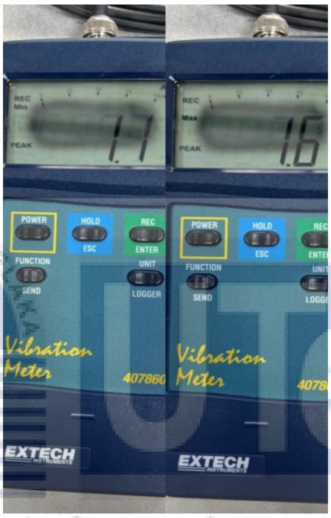

Figure 4.6 Display data on the actual vibration meter

Table 4.1 Acceleration of Three MPU6050s when Motor Speed is 10 RPM (Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s²)	Time (s)										Heavy-duty vibration accelerometer (m/s²)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	0	1	2	2	1	1	2	1	1	1.1	1.3
MPU1 X V3-V5	2	1	2	1	3	2	1	1	2	1	1.1	1.3
MPU2 X V6-V8	1	1	1	2	2	3	2	1	2	2	1.1	1.3

MPU Y V0-V2	2	0	1	1	1	2	3	2	2	1	1.1	1.6
MPU1 Y V3-V5	0	2	1	1	3	1	2	1	2	2	1.1	1.6

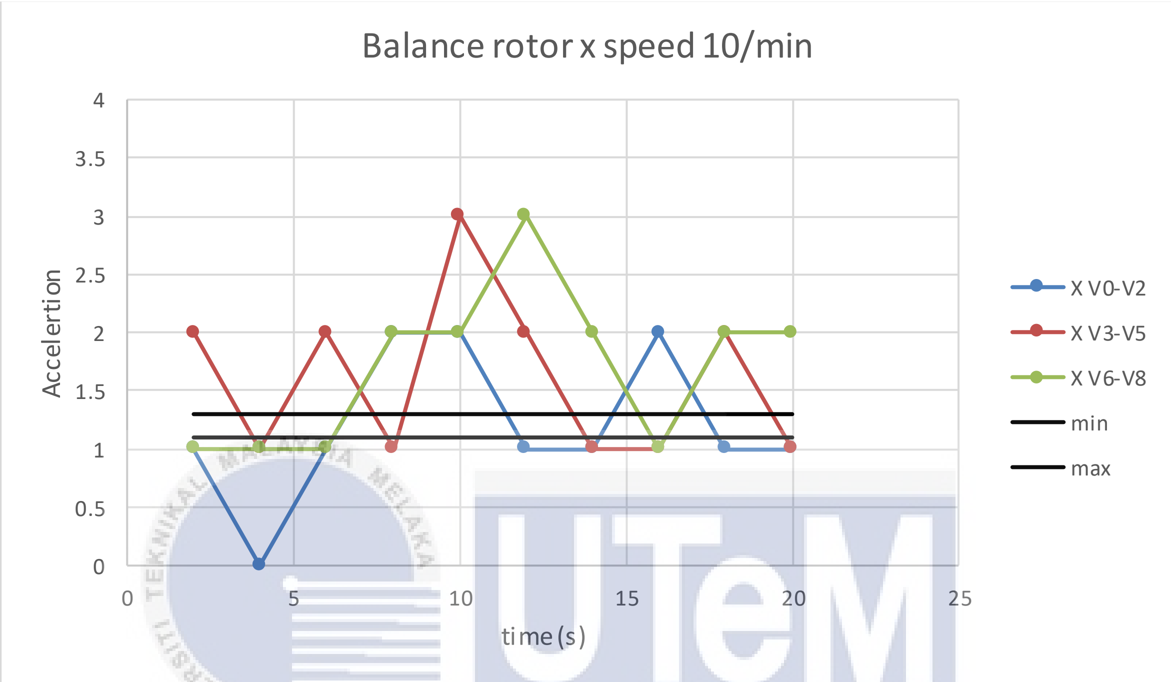

Figure 4.7 Acceleration X-axis versus Time for 10RPM speed

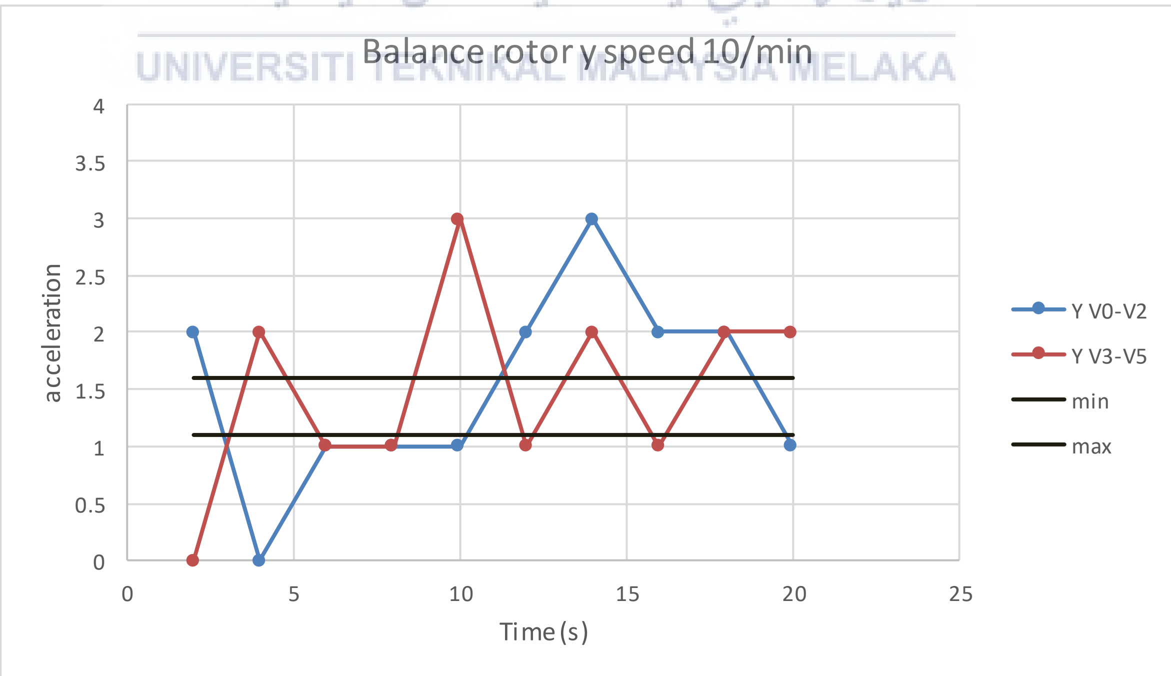

Figure 4.8 Acceleration Y-axis versus Time for 10RPM speed

Based on **Figure 4.7** and **Figure 4.8** shown the graphs of acceleration versus time of the low-cost vibration monitoring system which includes the Hibiscus Sense and two MPU6050 sensors performed when a balanced rotor was running at 10 RPM, the blue trend that name X V0-V2 represent the hibiscus sense, then the red trend name as X V3-V5 represent as first MPU6050 sensor the green trend name as X V6-V8 is represent as second MPU6050. For the Y axis the blue trend name as Y V0- V2 represents a hibiscus sense and the red trend name as Y V3- V5 is the first MPU6050. For y-axis, as the data shown in **Figure 4.8**. As we can see from these two figures that the data from the low-cost vibration monitoring system is higher than the actual vibration meter, it shows that it is more sensitive.

Table 4.2 Acceleration of Three MPU6050s when Motor Speed is 20 RPM (Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	0	2	2	1	1	0	1	1.1	1.6
MPU1 X V3-V5	1	1	0	2	2	1	2	1	2	1	1.1	1.6
MPU2 X V6-V8	1	1	0	1	1	2	1	1	2	2	1.1	1.6
MPU Y V0-V2	0	2	1	2	2	3	3	2	1	1	1.1	2.5
MPU1 Y V3-V5	1	1	2	3	3	2	1	1	0	1	1.1	2.5

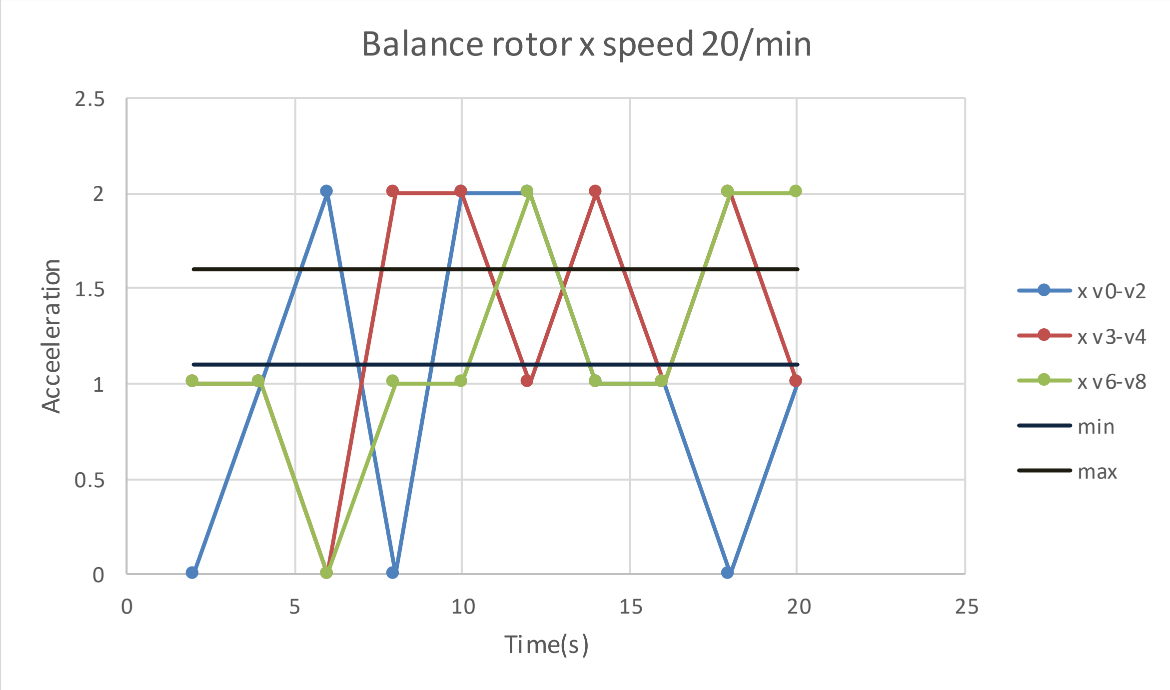

Figure 4.9 Acceleration X-axis versus Time for 20RPM speed

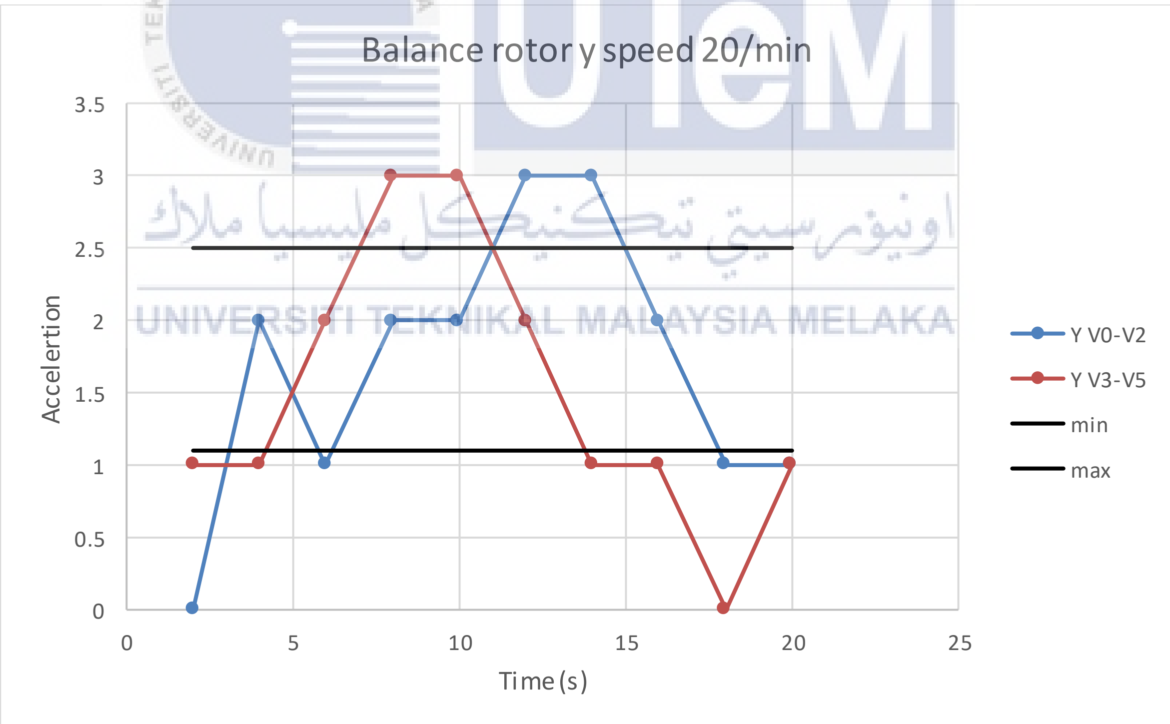

Figure 4.10 Acceleration Y-axis versus Time for 20RPM speed

As can be seen in the graph acceleration versus time in **Figure 4.9** and **Figure 4.10** that when the motor speed is being increase the vibration at the Y axis is higher than the X axis. The actual vibration meter also captures that the max in the Y axis is higher the X axis.

Table 4.3 Acceleration of Three MPU6050s when Motor Speed is 30 RPM (Balance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	2	0	1	2	1	1	2	1	2	1.1	1.7
MPU1 X V3-V5	1	1	2	1	1	2	1	0	2	1	1.1	1.7
MPU2 X V6-V8	1	2	1	2	2	1	2	0	1	2	1.1	1.7
MPU Y V0-V2	0	1	2	2	2	3	2	3	1	1	1.1	2.7
MPU1 Y V3-V5	0	2	2	1	2	0	2	1	2	1	1.1	2.7

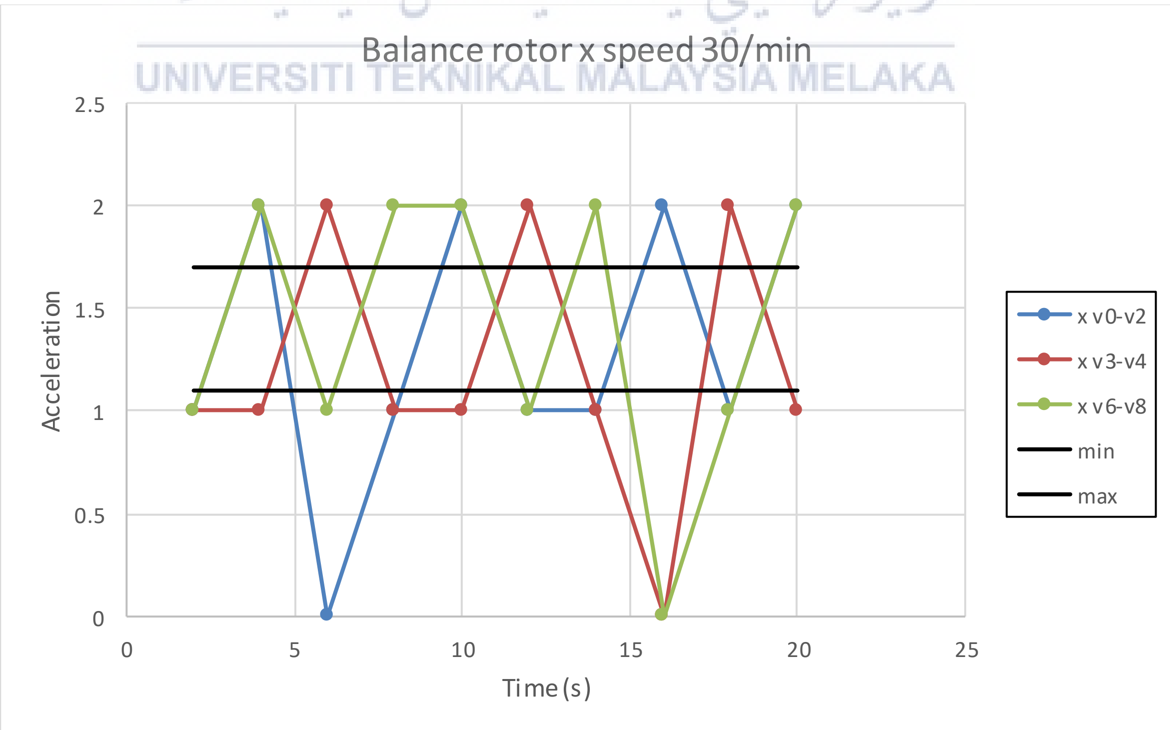

Figure 4.11 Acceleration X-axis versus Time for 30RPM speed

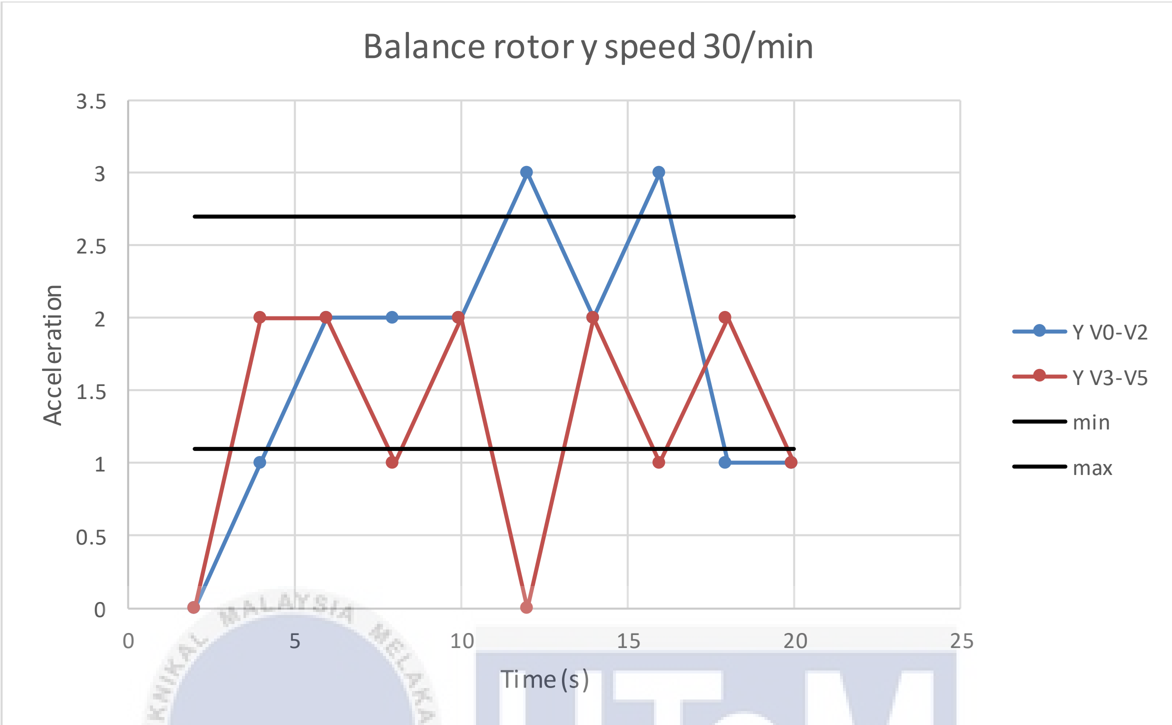

Figure 4.12 Acceleration Y-axis versus Time for 30RPM speed

From the graphs as in **Figure 4.11** and **Figure 4.12** the acceleration versus time it also shown that the for the Y axis for both the actual vibration meter and the low-cost vibration monitoring system is higher than the x axis. The increase of the data of the vibration is significant as the 20 RPM speed on the balance rotor. as we can see that the hibiscus sense and the MPU6050 is also sensitive and constantly generate data that are as the actual vibration meter.

In conclusion, this section demonstrates that the MPU6050 and the hibiscus sense may be utilized for vibration analysis because there isn't any extreme data under the balanced conditions that the machinery failure simulator simulates. The Blynk collected data during the machine run demonstrates regular patterns and real-time response, as seen by the data recorded in the x and y axis using the low-cost vibration monitoring equipment. The minimum and maximum vibration meter values were exactly matched by the system's consistent ability to capture vibrations along the x axis. The system managed to maintain synchronization and real-time response as y axis. An additional demonstration of the system's accuracy and consistency in recording dynamic changes in vibration levels along the x and y axis came from a comparison with a real vibration meter. It demonstrates that the system is an adaptable and effective tool for tracking vibration along several axes in various operational situations.

4.2.2 Under Unbalanced condition

As for the unbalanced condition, the machinery fault simulator creates unbalanced condition when there are three bolts and nuts added on the rotor. When the motor speed was adjusted to 10 RPM, 20 RPM, and 30 RPM, respectively, data was gathered. The computer's screen recorder also records data from the Blynk dashboard. For the data analysis in section **4.2.3**, the results in this section are presented in tabular and graphical form.

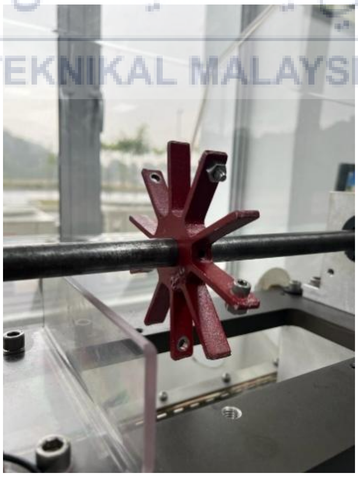

Figure 4.13 Rotor with bolts and nuts

Table 4.4 Acceleration of Three MPU6050s when Motor Speed is 10 RPM

(Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	1	2	2	1	2	2	1	3	2	1	1.1	1.5
MPU1 X V3-V5	1	1	2	1	2	3	2	1	2	2	1.1	1.5
MPU2 X V6-V8	0	3	1	2	1	0	3	2	2	3	1.1	1.5
MPU Y V0-V2	1	2	1	1	2	3	3	2	2	1	1.1	2.4
MPU1 Y V3-V5	0	2	1	2	2	1	2	2	1	0	1.1	2.4

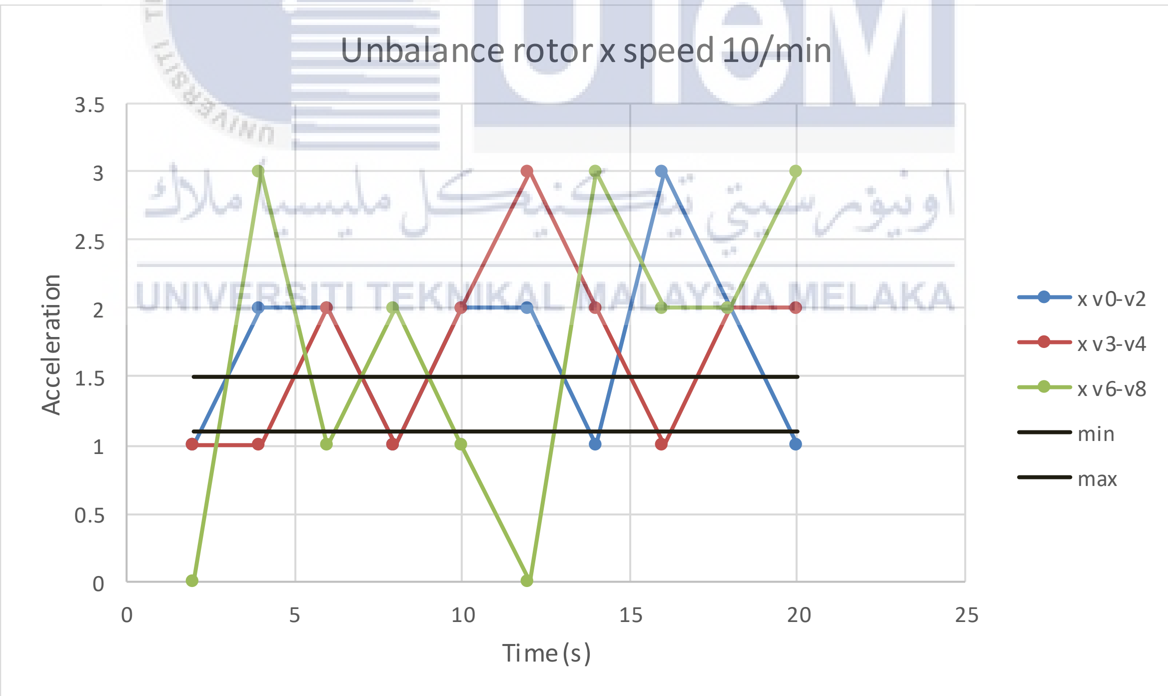

Figure 4.14 Acceleration X-axis versus Time for 10RPM speed

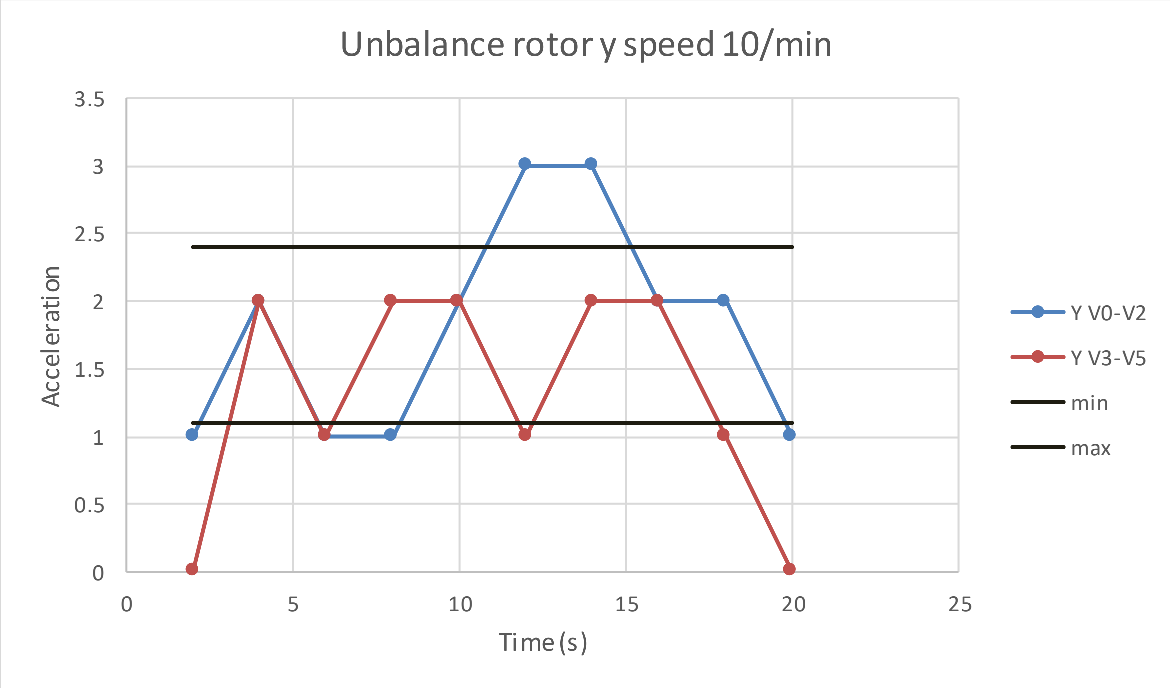

Figure 4.15 Acceleration Y-axis versus Time for 10RPM speed

Based on **Figure 4.14** and **Figure 4.15**, the graphs of acceleration versus time for the unbalanced rotor that run speed of 10RPM. The low-cost vibration monitoring system which includes the Hibiscus Sense and two MPU6050 sensors performed when a balanced rotor was running at 10 RPM, the blue trend that name X V0-V2 represent the hibiscus sense, then the red trend name as X V3-V5 represent as first MPU6050 sensor the green trend name as X V6-V8 is represent as second MPU6050. For the Y axis the blue trend name as Y V0- V2 represents a hibiscus sense and the red trend name as Y V3 - V5 is the first MPU6050. As we can see from **Figure 4.14** the data that was generated by the hibiscus sense and the MPU6050 is higher than the actual vibration meter.

Table 4.5 Acceleration of Three MPU6050s when Motor Speed is 20 RPM (Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s^2)	Time (s)										Heavy-duty vibration accelerometer (m/s^2)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	2	2	1	1	2	2	0	1.1	1.8
MPU1 X V3-V5	2	2	1	1	3	2	3	1	1	2	1.1	1.8
MPU2 X V6-V8	1	2	1	0	1	1	2	2	1	0	1.1	1.8
MPU Y V0-V2	1	2	0	2	3	3	2	2	1	1	1.1	2.7
MPU1 Y V3-V5	0	2	1	2	3	2	2	1	0	1	1.1	2.7

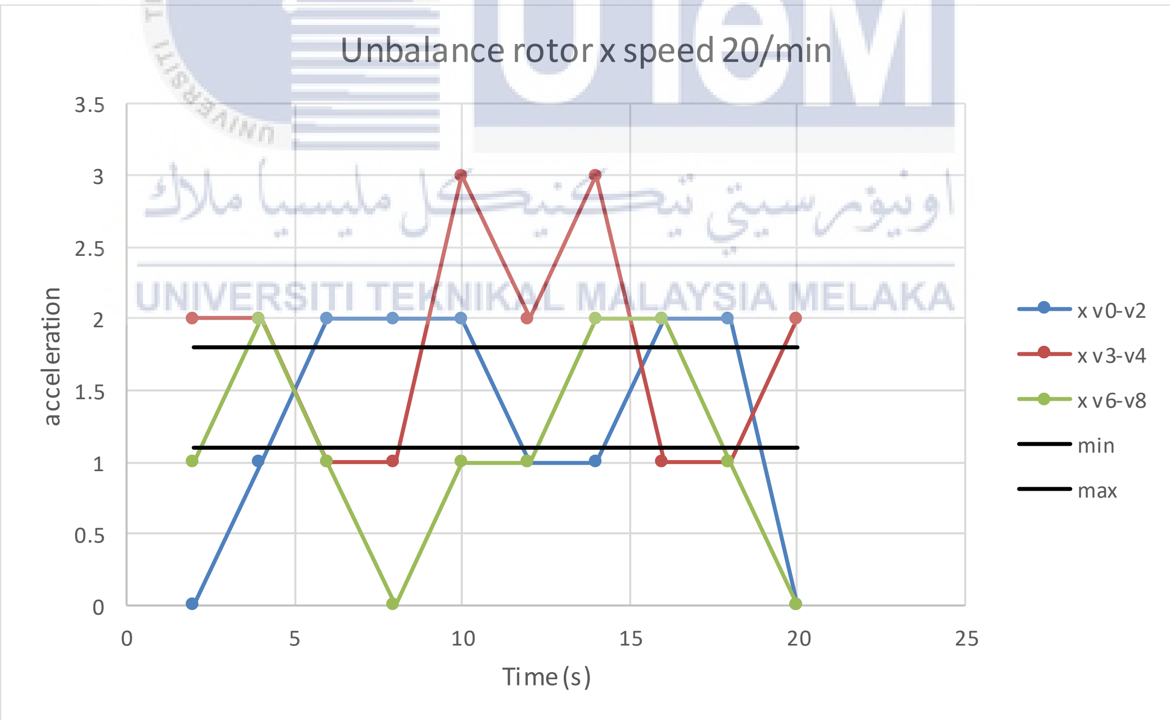

Figure 4.16 Acceleration X-axis versus Time for 20RPM speed

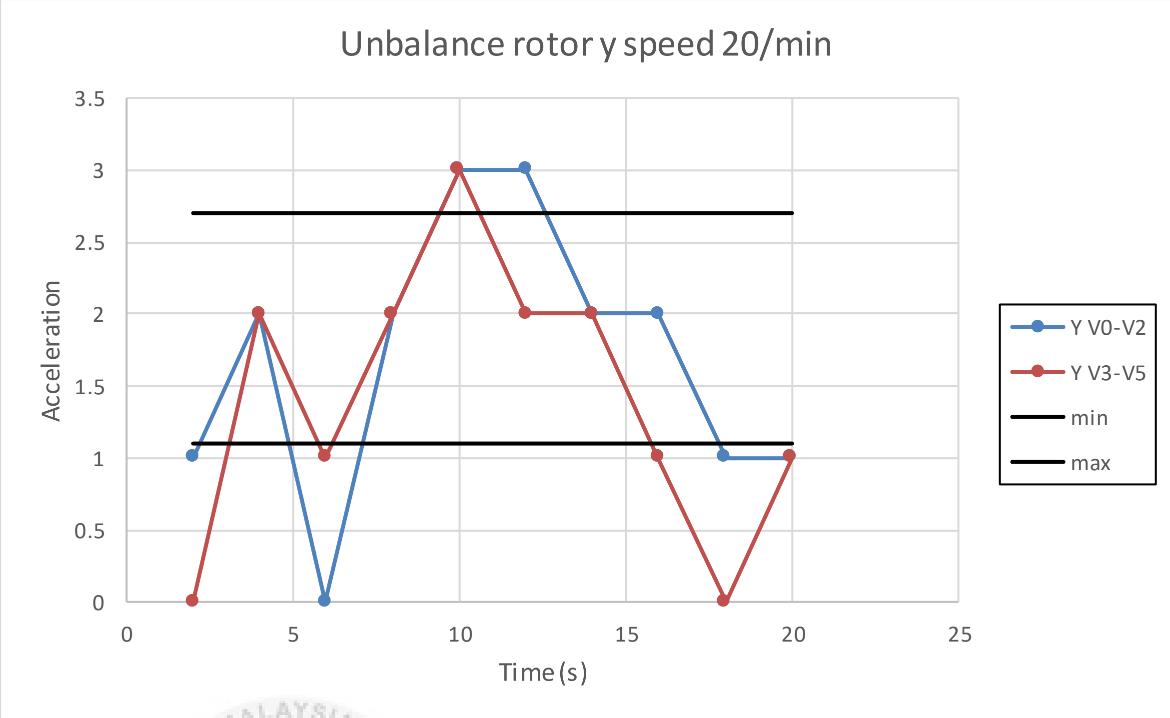

Figure 4.17 Acceleration Y-axis versus Time for 20RPM speed

As can be seen in the graph acceleration versus time in **Figure 4.16** and **Figure 4.17** that when the motor speed is being increase the vibration at the first MPU6050 that is name as X V3- V5 is higher than the hibiscus sense and the second MPU6050.

Table 4.6 Acceleration of Three MPU6050s when Motor Speed is 30 RPM (Unbalance Rotor)

Low-cost vibration monitoring system (Acceleration) (m/s²)	Time (s)										Heavy-duty vibration accelerometer (m/s²)	
	2	4	6	8	10	12	14	16	18	20	MIN	MAX
MPU X V0-V2	0	1	2	2	2	1	2	1	1	0	1.1	2.2
MPU1 X V3-V5	1	2	1	2	2	1	2	2	1	2	1.1	2.2
MPU2 X V6-V8	0	2	2	1	3	2	1	2	2	1	1.1	2.2

MPU Y V0-V2	1	2	2	3	4	3	4	2	3	2	1.1	3.8
MPU1 Y V3-V5	1	2	3	2	3	3	4	3	2	1	1.1	3.8

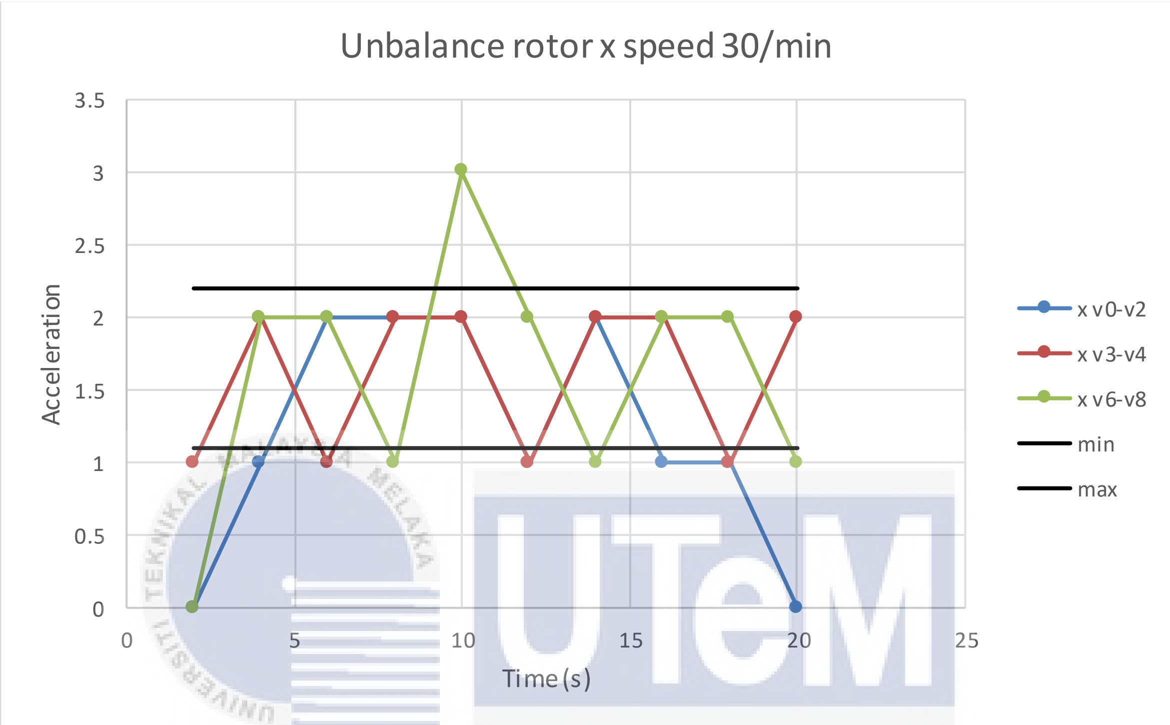

Figure 4.18 Acceleration X-axis versus Time for 30RPM speed

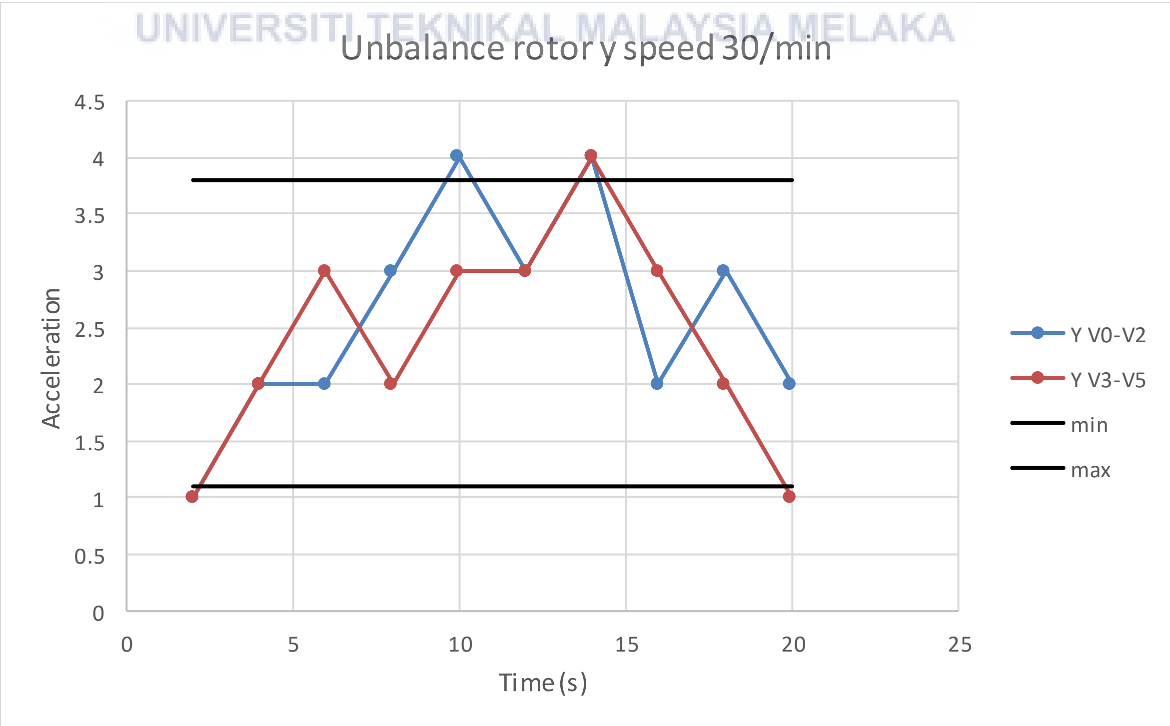

Figure 4.19 Acceleration Y-axis versus Time for 30RPM speed

From the graphs as in **Figure 4.18** and **Figure 4.19** the acceleration versus time it shown that the X axis and the Y axis for both the actual vibration meter and the low-cost vibration monitoring system is same in the range of data. The increase of data for vibration is significant from the speed of 10 RPM, 20 RPM and 30 RPM speed on the unbalance rotor. as we can see that the hibiscus sense and the MPU6050 is also sensitive and constantly generate data that are as the actual vibration meter.

4.2.3 Data Analysis

Data comparisons under balanced and unbalanced conditions will be carried out in this part. This section aims to demonstrate that industrial vibration analysis can be conducted with the project's integrated low-cost vibration monitoring system. The data under balanced conditions is shown on the left graph in the figures below, whereas the data under unbalanced conditions is shown on the right graph.

Figure 4.20 graph when motor speed is 10RPM.

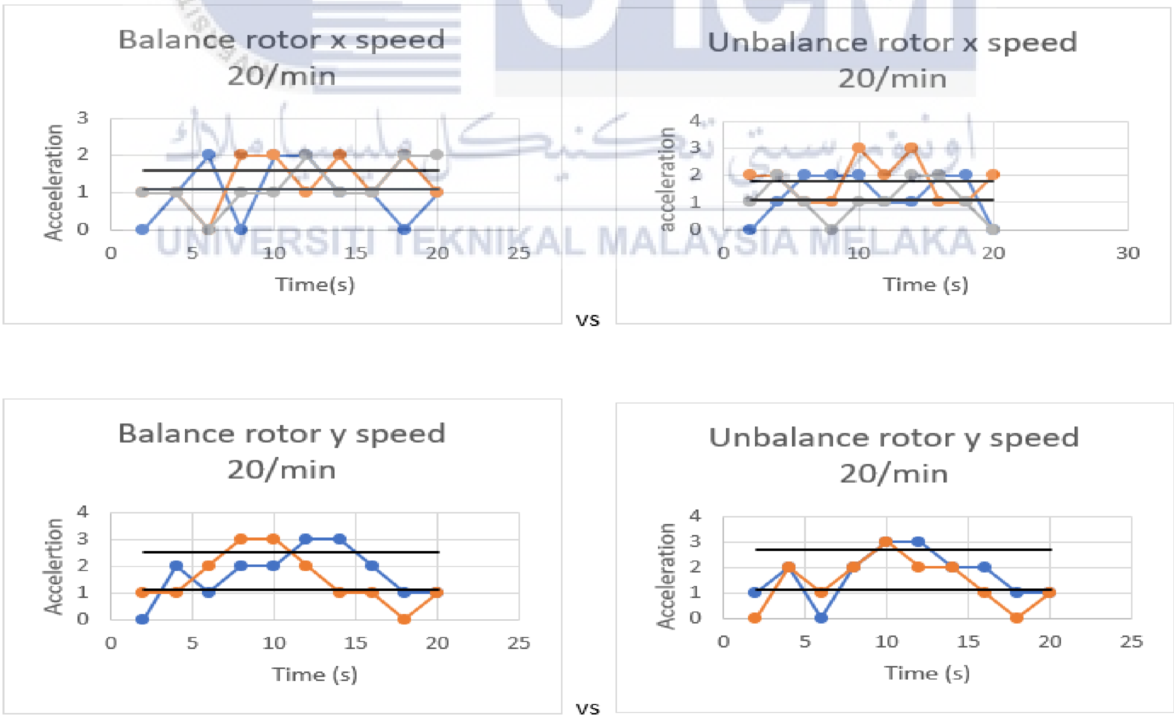

Figure 4.21 graph when motor speed is 20RPM.

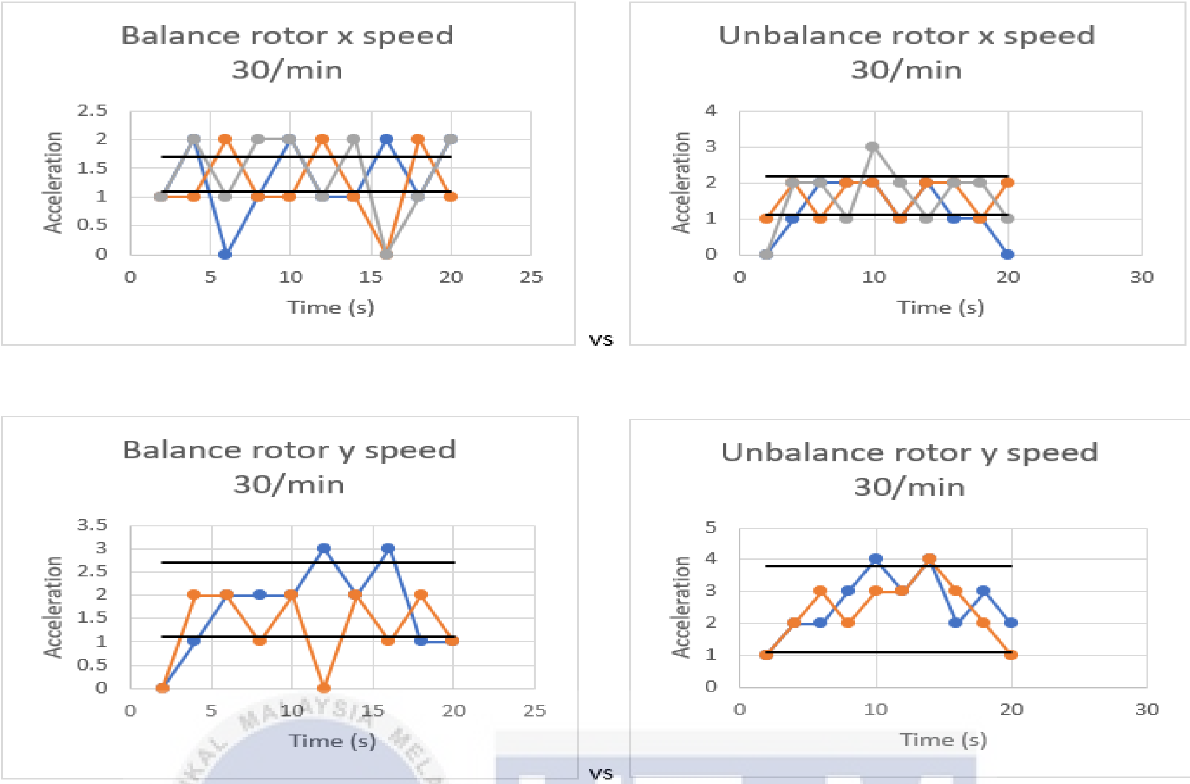

Figure 4.22 graph when motor speed is 30RPM.

The graphs of acceleration vs time for each axis taken from sections **4.2.1** and **4.2.2** are shown in **Figures 4.20**, **Figures 4.21**, and **Figures 4.22**, for both the actual vibration meter and the integrated low-cost vibration monitoring system, it is observable that the difference between trend points in the unbalanced situations is greater than the balance in the x-axis and y-axis. **Figure 4.21** illustrates how the balance and unbalance conditions show an almost similar pattern. This could potentially be attributed to systematic mistakes in the measuring method caused by the environment. **Figures 4.20**, **4.21**, and **4.22** make it abundantly evident that the greater the motor speed, the greater the variation in the data displayed between the trend point under balanced and unbalanced conditions. Thus, the data comparison in this part shows that the industrial vibration analysis could be conducted with the project's integrated low-cost vibration monitoring system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

For the conclusions of this project report. Two free interface programmes are being used in this project, the first one is Blynk application programme and the second programmes is Arduino IDE, were used for this project in order to build an integrated, low-cost vibration monitoring system. The coding for the vibration monitoring system was successfully generated using the Arduino IDE programme. The integrated accelerometer MPU6050 of Hibiscus Sense is controlled by the microcontroller, and the other two accelerometer GY-521 MPU6050 senses vibration and transmits the information it detects to the microcontroller. Through the mobile phone wifi connection, the microcontroller will also send the received data to the Blynk programme.

The Blynk programme is also effectively used to present the data in gauge charts form. Hibiscus Sense and Blynk software have established a successful wifi connection. The wireless connection between the system hardware and software enabled the successful creation of a wireless integrated low-cost vibration monitoring system.

Based on the project outcomes the ability of the built-in accelerometer MPU6050 and the accelerometer GY-521 MPU6050 to make comparison between vibration patterns in the x, and y axis under balanced and unbalanced rotor situations was confirmed based on the results that we get. Thus, it shows that industrial vibration analysis may be performed using the project's integrated, low-cost vibration monitoring system.

In conclusion, a wireless integrated low cost vibration monitoring system was successfully built through the verification of the results, and the data also has been validate with the actual vibration meter in the lab. It indicating that the system has met the project's goals. The IoT vibration monitoring evaluation project aim has been accomplished by the vibration monitoring system since it has been added another sensor and it can transmit data to Blynk software over a wifi connection, and Blynk stores the data in its IoT cloud.

5.2 Installation Suggestion

In particular, this section discusses the recommendation for installing of low-cost vibration monitoring devices for machinery vibration analysis in industrial environments. To fully utilise these devices, an easy and efficient installation procedure is essential.

5.2.1 Installation Procedure

The recommendations for implementing low-cost vibration monitoring systems for machinery vibration analysis in industry will be the primary focus of this section. For the main things that are needed in this project is the Arduino IDE software (version 1.8.19) or the latest version of the software, then the libraries needed for code upload must be downloaded and installed by users. Hibiscus Sense requires the user to enter their Wi-Fi name and password in a designated line of the code for it to connect to the network before uploading the code for the low-cost vibration monitoring system to Hibiscus Sense.

when the code upload, users must get into the Blynk IoT website, log in with the provided account, and view the specified device from the device list to ensure the connection between Hibiscus Sense and Blynk software. when it shows an online icon on the dashboard of the Blynk applications, Hibiscus Sense has successfully connected to Blynk, and it is ready to operate. If the status is offline, the code needs to be reviewed and uploaded again since the Wi-Fi name and password were input improperly.

By using the included magnets at the bottom of the Hibiscus Sense and GY- 521 MPU6050 casing, the user must place the Hibiscus Sense on top of the machine's measuring motor. By using a longer jumper wire connecting Hibiscus Sense and the MPU6050, the device may be positioned at multiple points on the machine to detect vibrations from various sources and various point, such as shafts and gears. The user can attach Hibiscus Sense and MPU6050 to the top of the motor using magnet that are attach behind the casing. In case the motor case is made of non-metallic material using a heavy-duty double-sided tape is possible. Using magnets or sturdy double-sided tape, the power bank can be fastened to the machine casing or can put on a flat surface surrounding the motor that is being tested. Then after settle setup the vibration sensor, the machine can be run and the after that can refresh the Blynk application to observe the real time vibration data that generated by the vibration monitoring system.

5.2.2 Sensor Placement

One of the most important ways to maximise the effectiveness of low-cost vibration monitoring systems in industrial machinery is to put the sensors strategically. The specific selection and placement of sensors are essential for gathering extensive vibration data that is very important for further examination. By locating the critical locations on the equipment where vibrations are most noticeable and have the most analytical value. These critical locations are usually those that are near rotating parts and those that experience higher amounts of stress during normal operation. The monitoring system gets skilled at collecting subtle vibration patterns by carefully positioning sensors at these crucial spots, allowing for a more complete and precise examination of machinery operation.

5.2.3 Power Supply Consideration

When implementing low-cost vibration monitoring systems into industrial machinery, power supply must be taken into account. Selecting a reliable and stable power supply is essential to guarantee the ongoing and continuous functioning of the monitoring system.Reducing the possibility of data gaps is the main reason for emphasising a steady power supply, particularly during crucial operational times. In this project, the vibration monitoring system is powered entirely by a 5000mAh battery bank. For this project, the integrated low cost vibration monitoring system has actually been powered by power banks or Lithium Polymer (LiPo) batteries with a capacity of 4000 mAh and more. For this project, a 5000mAh power bank was selected because the capacity of its battery can make it last longer.

5.2.4 Wireless Connectivity setup

The initial key in maximising the performance of low-cost vibration monitoring devices in industrial machinery is setting up wireless connectivity. For the monitoring system to function well in industrial environments, a strong wireless communication configuration is necessary. The system will provide vibration data in real-time in Blynk monitoring applications by safely connecting to the Wi-Fi network.

5.2.5 Vibration Monitroing on Blynk Application

To monitor vibrations, users can download the Blynk smartphone app or by acessing it through google and using the website. Initially, for the smartphone application users must sign in using the same account that they use to access the Blynk website. After that, the user can turn on the specified device and see the data shown on the Blynk app's dashboard. Five phones or other devices can access the Blynk app for vibration monitoring at once for free

Blynk software users. Customers can upgrade to a plus account or higher on Blynk to enable more users to access the programme.

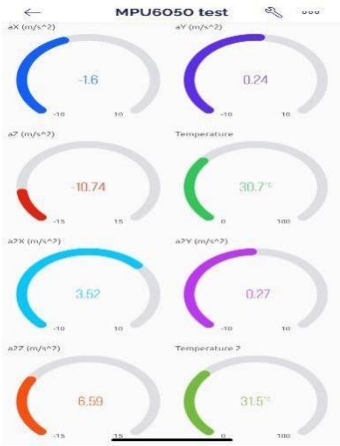

Figure 5.1 Dashboard of Blynk on Mobile

5.3 Improvement recommendations

The project's integrated low-cost vibration monitoring system will look better and seen more manageable if heat shrink tube is used to hide the jumper wire between the Hibicsus Sense and the two MPU6050. Electrical cables are wrapped in heat shrink tubes, which are shrinkable insulators. Heat causes the tubing to contract, turning the jumper into a single cable and preventing the jumper connectors from coming loose. In order to decrease the size of the vibration monitoring system, it is also possible to make some special order of the housing for the Hibiscus Sense and the two accelerometer MPU6050 from online or physical retailers. The housing that are being order can fit the hibuscus sense and the MPU6050 sensor perfectly, and the material of the housing should be thin and durable this is to ensure that the sensor can detect the vibration of the machine. Besides Solar cells could eventually be used to replace the vibration monitoring system's power source, which would address the issue of charging and replacing when the power bank or LiPo battery is insufficient. Besides is upgrade it by adding on the solar cells. It will make the low-cost vibration monitoring system more save and more durable. Last but not least is about the blynk iot software, the software can be upgraded to the subscribe account so that it could give more valuable data and can make it more easier on recording the data.

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GcBdzveKKCDNC983WilBmfoYuG5fRF8XI2l1IdKUlU0w5stwfKTHvYVJfgefC
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APPENDICES

APPENDIX A Result of Turnitin

PSM Report

ORIGINALITY REPORT

18%	10%	6%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Fr Gabriel Richard High School Student Paper	3%
2	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	1%
3	mobilityforesights.com Internet Source	1%
4	www.mdpi.com Internet Source	1%
5	Submitted to Universiti Teknologi Malaysia Student Paper	1%
6	eprints.utem.edu.my Internet Source	1%
7	Submitted to University of South Australia Student Paper	1%
8	Juan Carlos A. Jauregui Correa, Alejandro A. Lozano Guzman. "Spectral analysis", Elsevier BV, 2020 Publication	1%

APPENDIX B   PSM1 Gantt Chart

Gantt Chart for PSM 1																
No	**Task Project**	**Plan / Actual**	**Week**													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	PSM title registration	Plan														
		Actual														
2	Project briefing with supervisor.	Plan														
		Actual														
3	Find the journal, thesis, and article for literature review	Plan														
		Actual														
4	Research about required components vibration	Plan														
		Actual														
5	Planning the project workflow	Plan														
		Actual														
6	Make a flowchart of project workflow	Plan														
		Actual														
7	Study about the software of vibration monitoring system	Plan														
		Actual														
8	Adding and checking references	Plan														
		Actual														
9	Sending full report for checking to supervisor	Plan														
		Actual														
10	Modify report and add appendix	Plan														
		Actual														
11	Upload the revised report on e-PSM	Plan														
		Actual														
12	Upload revised report on e-PSM	Plan														
		Actual														

APPENDIX C PSM2 Gantt Chart

Gantt Chart for PSM 2																	
No	**Task Project**	**Plan / Actual**	**Week**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	PSM 2 briefing	Plan														
		Actual														
2	Find the sensor and the part needed	Plan														
		Actual														
3	Create the code for the vibration monitoring system	Plan														
		Actual														
4	Do research on Blynk software and create code	Plan														
		Actual														
5	Testing the wired connection between the system and software	Plan														
		Actual														
6	Testing the wireless connection between the system and software	Plan														
		Actual														
7	Adding new casing for the main components and modified system	Plan														
		Actual														
8	Setup the experiment	Plan														
		Actual														
9	Record the experiment data	Plan														
		Actual														
10	Sending full report to supervisor for checking	Plan														
		Actual														
11	Modify report and add appendix	Plan														
		Actual														
12	Upload the revised report on e-PSM	Plan														
		Actual														
13	Upload revised report on e-PSM after presentation	Plan														
		Actual														

APPENDIX D Overview of Code Integrated Low Cost Vibration Monitoring System

```
#define BLYNK_TEMPLATE_ID "TMPL6GxMHY3em"
#define BLYNK_DEVICE_NAME "MPU6050"
#define BLYNK_AUTH_TOKEN "w9EWZiNXjuFCRJALJt9kCOAvbv-ec-Eb"
#define BLYNK_PRINT Serial
#include <Wire.h>
#include <BlynkSimpleEsp32.h>
#include <Adafruit_MPU6050.h>

char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "iPhone (3)";
char pass[] = "12345678";

Adafruit_MPU6050 mpu;   // Hibiscus Sense ESP32
Adafruit_MPU6050 mpu1;  // First MPU6050 sensor
Adafruit_MPU6050 mpu2;  // Second MPU6050 sensor

void setup(void) {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass);
  Wire.begin();
  mpu.begin(0x68);
  mpu1.begin(0x69);
  mpu2.begin(0x6A);
}

void loop() {
  Blynk.run();
  Getmpu(mpu, V0, V1, V2);    // Hibiscus Sense - X axis
  Getmpu(mpu1, V3, V4, V5);   // First MPU6050 - Y axis
  Getmpu(mpu2, V6, V7, V8);   // Second MPU6050 - Z axis
  delay(2000);
}


void Getmpu(Adafruit_MPU6050& sensor, int xPin, int yPin, int zPin) {
  sensors_event_t a, g, temp;
  sensor.getEvent(&a, &g, &temp);

  Blynk.virtualWrite(xPin, a.acceleration.x);
  Blynk.virtualWrite(yPin, a.acceleration.y);
  Blynk.virtualWrite(zPin, a.acceleration.z);
}
```