



Advanced Fault Detection And Identification In Brushless Dc Motors Using Iot

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Abstract: Due to their high efficiency, dependability, and low maintenance requirements, brushless DC (BLDC) motors are utilized extensively in industrial automation, electric vehicles, and consumer electronics. However, undetected faults in these motors—such as phase imbalance, bearing wear, rotor misalignment, or overheating—can lead to system failures and costly downtimes. Utilizing the potent capabilities of the ESP32 microcontroller and Internet of Things (IoT) technology, this project proposes an advanced fault detection and identification (FDI) system for BLDC motors. The system continuously monitors key motor parameters such as voltage, current, temperature, and vibration using a combination of analog and digital sensors. Real-time signal processing, anomaly detection, and wireless communication all make use of the ESP32. The microcontroller's lightweight machine learning algorithms and threshold-based logic are used to identify fault conditions, ensuring prompt and accurate fault recognition. Detected faults and operational data are transmitted via Wi-Fi or MQTT protocols to a cloud-based IoT dashboard, enabling real-time remote monitoring, data visualization, and timely notifications through web or mobile interfaces. This approach supports predictive maintenance and enhances overall system reliability. Experimental testing on a BLDC motor testbed substantiates the implementation's efficacy in early fault detection, low-latency communication, and seamless IoT platform integration. The project demonstrates the potential for next-generation motor health monitoring solutions by combining smart diagnostics with embedded IoT.

1. INTRODUCTION

Fault detection in DC brushless motors (BLDC) is a critical task that ensures the reliable and efficient operation of various applications, including electric vehicles, drones, and industrial machinery. Anomalies in BLDC motors can lead to performance degradation, energy loss, premature wear, and even catastrophic failures. These failures can have significant consequences, ranging from inconvenience and downtime to safety hazards and financial losses. Therefore, developing robust and effective fault detection systems is essential to maintain the integrity and reliability of BLDC motor-driven systems.

BLDC motors are highly efficient and reliable, but they are not immune to faults. Common faults in BLDC motors include short circuits, overloads, phase imbalance, overheating, bearing failures, and misalignment. These faults can be caused by various factors, such as manufacturing defects, improper installation, excessive loads, environmental conditions, or normal wear and tear.

Detecting faults in BLDC motors early can help to prevent more serious problems and reduce downtime. It can also help to improve the overall efficiency and reliability of the system. There are a number of different methods that can be used to detect faults in BLDC motors, including monitoring the motor's current, temperature, vibration, and noise.

Current monitoring is one of the most common methods of fault detection in BLDC motors. By monitoring the motor's current draw, it is possible to detect short circuits, overloads, and phase imbalance. Temperature monitoring is another important method of fault detection. By monitoring the motor's

temperature, it is possible to detect overheating, which can be a sign of a mechanical problem or a short circuit. Vibration monitoring is also a useful method of fault detection. By monitoring the motor's vibration, it is possible to detect bearing failures and misalignment. Noise monitoring is a less common method of fault detection, but it can be used to detect bearing failures and other mechanical problems.

2. LITERATURE REVIEW

2.1 A Simple and Efficient Current-Based Method for Interturn Fault Detection in BLDC Motors

This paper provides a tutorial on induction motors signature analysis as a tool for fault detection. It focuses on motor current signature analysis, which uses spectral analysis of stator current. The paper is written without "state-of-the-art" terminology, aiming to benefit practicing engineers who may not be familiar with signal processing. It aims to introduce the fundamental theory, main results, and practical applications of motor signature analysis for detecting abnormal electrical and mechanical conditions that may lead to induction motor failure.

2.2 Fault Detection and Diagnosis of Winding Short in BLDC Motors Based on Fuzzy Similarity:

The turn-to-turn short is a common fault in brushless DC motors (BLDC) and can occur frequently. To detect winding faults, several methods have been applied, focusing on current signals. In this study, current sensors were installed to measure signals for fault detection of BLDC motors. Park's vector method was used to extract features and isolate faults from the current measured by sensors. This method considers three-phase current values, making it useful to detect features from one-phase and three-phase faults..

After extracting two-dimensional features, the final feature was generated using the two-dimensional values using the distance equation. Fuzzy similarity was applied to isolate the faults, which can be used without model generation and convert the fault into a percentage value that can be considered as a possibility of the fault. Fuzzy similarity is an available tool to diagnose the fault without model.

2.3 A Simple and Efficient Current-Based Method for Interturn Fault Detection in BLDC Motors

This article introduces a simple and efficient method to detect interturn faults in Brushless Direct Current (BLDC) motors based on one modal current and four different simple indices. The modal current is derived by proper linear mixing of measured three-phase currents, leading to an asymmetrical condition. Three main indices, including moving mean, variance, and signal energy, are obtained in parallel after the initial processing of the modal current. An auxiliary correlation-based index is suggested to enhance the method for discrimination of faulty conditions from healthy ones. The fault detection is made by passing at least two main indices (out of three indices), and also an auxiliary index from a predefined threshold. The proposed technique is evaluated under different loads, speeds, and fault severities in two different datasets: data from a simulated motor in Maxwell finite element package and a real four-pole motor. The results confirm a high accuracy and quick fault detection in the proposed approach.

Many techniques have been proposed for fault diagnosis of BLDC motors, such as search coil sensors, magnetic field variations, parameter estimation-based techniques, electromagnetic torque signal, and stator input current frequency pattern. However, these methods have their main drawbacks, such as high computational burden and high demand for inputs.

2.4 Multiple Sensor Fault Detection Algorithm for Fault Tolerant Control of BLDC Motor:

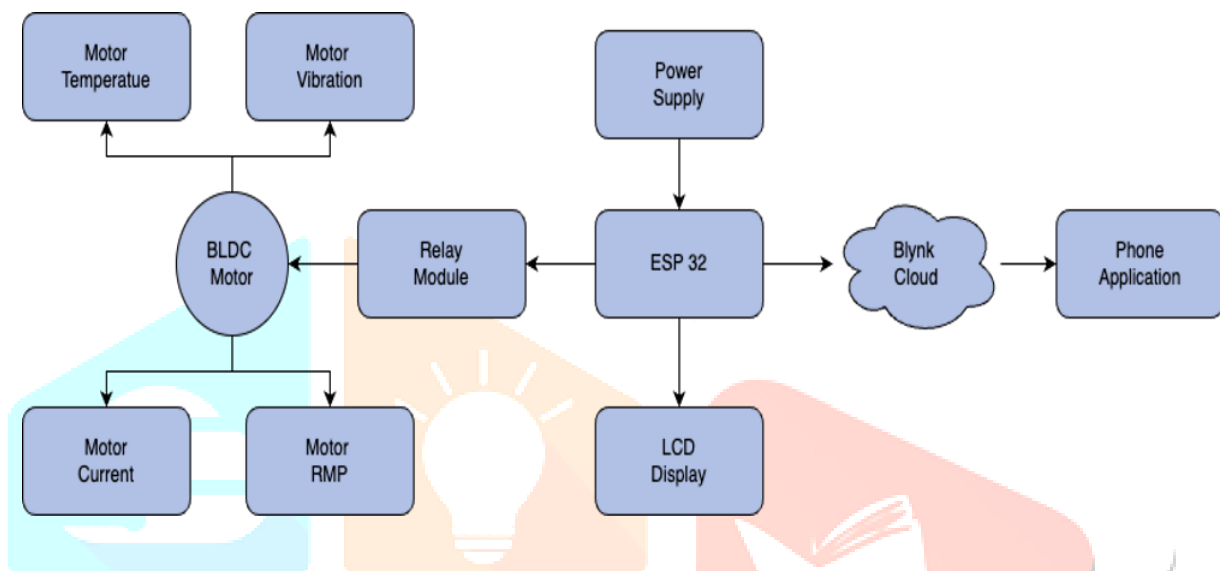
The paper proposes a direct redundancy-based fault tolerant control system (FTCS) for the operation of a brushless DC (BLDC) motor in case of multiple sensor failures. The proposed method expands on previous work that dealt with the failure of a single Hall-effect sensor. A novel algorithm and experimental scheme are developed, allowing the FTCS to deal with the failure of up to two Hall-effect sensors.

The fault tolerant control (FTC) algorithm is based on three conditions and is designed to deal with any scenario of sensor faults. Simulations were performed, and experimental results show the effectiveness and validation of the method. The method can be implemented easily, is fast, and does not require high-end processors.

Brushless DC (BLDC) is a type of PMSM used for propulsion in modern electric vehicles, and Hall-effect sensors provide the required rotor position for motor control. When one of the Hall-effect sensors becomes faulty or damaged, motor operation is severely affected, and after two sensor failures, the motor comes to a complete stop. This can result in dangerous and life-threatening situations in the aerospace or automotive industries.

FTCS is required to maintain motor operation with the damaged sensor, keeping the motor operational until maintenance can be performed or the damaged part can be replaced. A BLDC motor system may suffer from various types of faults, such as winding-related, inverter-related, or position sensor-related faults. Intelligent control systems can completely remediate position sensor faults using FTC.

3. Block Diagram:



3.1 Working Principle:

The vehicle may move normally on the road in a fixed speed. When the speed exceeds and tilting of vehicle happens, the tilting is sensed by the MPU 6050, which is a combination of accelerometer and gyroscope. MPU 6050 senses the tilting of vehicle continuously and sends the signal to Arduino Uno. A threshold value of tilting will be already fixed. When Arduino Detects that the tilting is more than the fixed value then it can be assumed that an accident has occurred. All of a sudden, Arduino makes the GSM Module to send an alert message to the registered emergency numbers. Along with that, the longitude and latitude of the vehicle will be send to the registered number through GPS module. The purpose of ultrasonic sensors is much more highlighting. The ultrasonic sensors detect the distance between two vehicles. When the distance is sensed as too close then the driver can be alerted to slow sown or to apply the break. In addition, when the vehicles are close to each other the speed of vehicles are automatically set to low.

4. Hardware Requirements

- ESP32 Microcontroller
- LCD 16x2
- BLDC Motor
- Temperature Sensor
- Module Relay single channel 5v
- Blynk Cloud

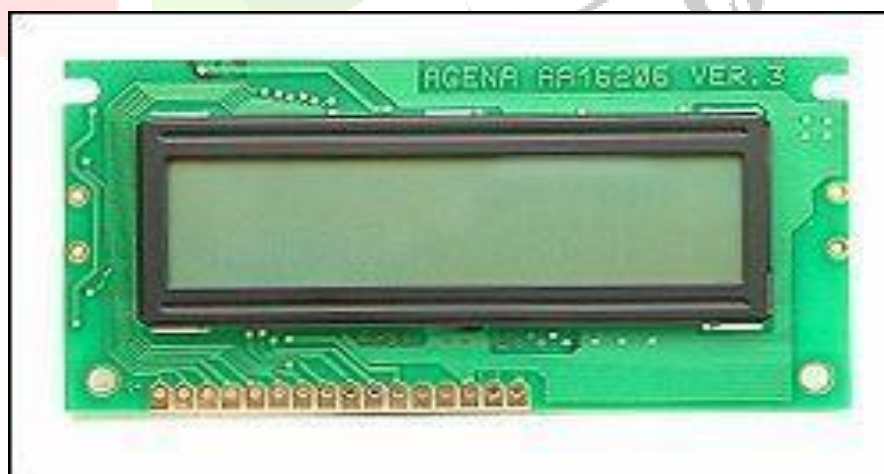
4.1 ESP32 Microcontroller



ESP32 is the SoC (System on Chip) microcontroller which has gained massive popularity recently. Whether the popularity of ESP32 grew because of the growth of IoT or whether IoT grew because of the introduction of ESP32 is debatable, the μ C should be able to perform basic processing of the incoming sensor data, sometimes at high speeds, and have sufficient memory to store the data. ESP32 has a max operating frequency of 40 MHz, which is sufficiently high. It has two cores, allowing parallel processing, which is a further add-on. Finally, its 520 KB SRAM is sufficiently large for processing a large array of data onboard. Many popular processes and transforms, like FFT, peak detection, RMS calculation, etc. can be performed onboard ESP32. On the storage front, ESP32 goes a step ahead of the conventional microcontrollers and provides a file system within the flash. Out of the 4 MB of onboard flash, by default, 1.5 MB is reserved as SPIFFS (SPI Flash File System). Think of it as a mini-SD Card that lies within the chip itself. You can not only store data, but also text files, images, HTML and CSS files, and a lot more within SPIFFS. People have displayed beautiful Webpages on WiFi servers created using ESP32, by storing HTML files within SPIFFS.

4.2 LIQUID CRYSTAL DISPLAY (LCD):

Most common LCDs connected to the microcontrollers are 16x2 and 20x2 displays. It is commonly used in various systems to show different status and parameters. LCD16x2 has 2 lines with 16 characters in each line. Each character is made up of a 5x8 (column x row) pixel matrix.

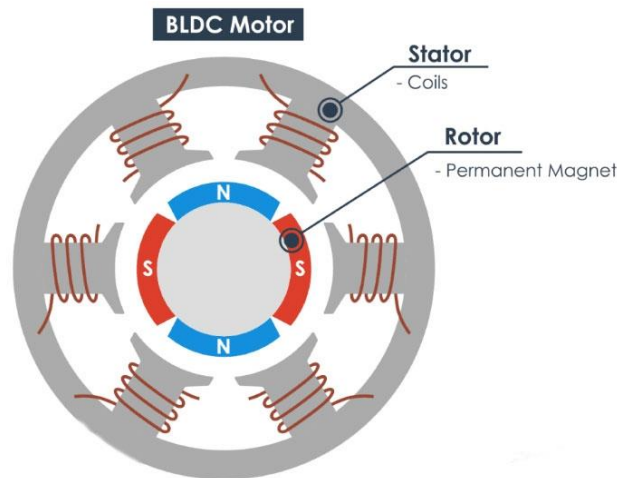


4.3 BLDC:

A Brushless DC Electric Motor (BLDC) is an electric motor powered by a direct current voltage supply and commutated electronically instead of by brushes like in conventional DC motors. BLDC motors are more popular than the conventional [DC motors](#) nowadays, but the development of these type of motors has only been possible since the 1960s when semiconductor electronics were developed.

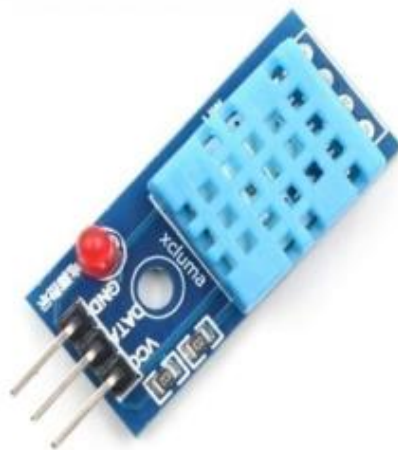
The simplest type of motor is the brushed DC motor. In this type of motor, electrical current is passed through coils that are arranged within a fixed magnetic field. The current generates magnetic fields in the coils; this causes the coil assembly to rotate, as each coil is pushed away from the like pole and pulled toward

the unlike pole of the fixed field. To maintain rotation, it is necessary to continually reverse the current—so that coil polarities will continually flip, causing the coils to continue “chasing” the unlike fixed poles. Power to the coils is supplied through fixed conductive brushes that make contact with a rotating commutator; it is the rotation of the commutator that causes the reversal of the current through the coils. The commutator and brushes are the key components distinguishing the brushed DC motor from other motor types.



4.4 Temperature Sensor:

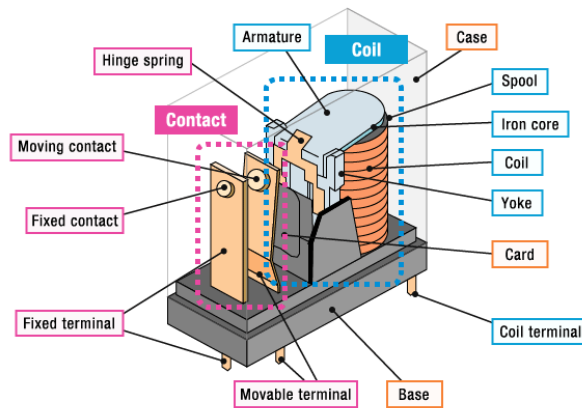
Temperature sensor is an integrated circuit sensor. The output voltage is linearly proportional to the centigrade temperature. The sensor shown in figure is compatible with Arduino UNO device. The applications of the temperature sensor are in microwave ovens, fridges, household devices, air conditioners, and atmosphere and water temperature monitoring. It can measure not only the hot bodies but also cold bodies. There are two types of sensors, they are noncontact temperature sensors and contact temperature sensors. Contact temperature sensors are again divided into three subtypes: electromechanical, resistive resistance temperature detectors, and semiconductor-based temperature sensors



4.5 Relay:

Relays are electrically operated switches that open and close the circuits by receiving electrical signals from outside sources. Some people may associate “relay” with a racing competition where members of the team take turns passing batons to complete the race.

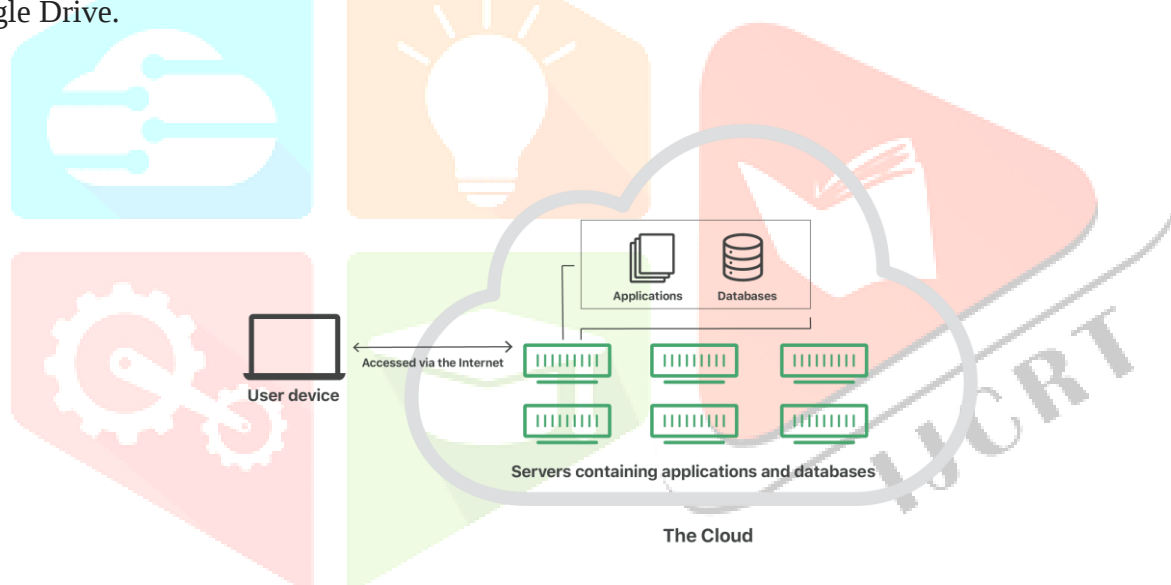
The “relays” embedded in electrical products work in a similar way; they receive an electrical signal and send the signal to other equipment by turning the switch on and off.



4.6 Blynk Cloud

"The cloud" refers to servers that are accessed over the Internet, and the software and databases that run on those servers. Cloud servers are located in [data centers](#) all over the world. By using cloud computing, users and companies do not have to manage physical servers themselves or run software applications on their own machines.

The cloud enables users to access the same files and applications from almost any device, because the computing and storage takes place on servers in a data center, instead of locally on the user device. This is why a user can log in to their Instagram account on a new phone after their old phone breaks and still find their old account in place, with all their photos, videos, and conversation history. It works the same way with cloud [email](#) providers like Gmail or Microsoft Office 365, and with [cloud storage](#) providers like Dropbox or Google Drive.



5. SOFTWARE REQUIREMENTS:

- Arduino IDE.
- C Programming

6. ADVANTAGES

- Advantages of the IoT-Based BLDC Motor Fault Detection System:
- Proactive maintenance: Detects and diagnoses motor faults early, preventing unexpected breakdowns and reducing downtime.
- Improved efficiency: Optimizes motor performance by identifying and addressing issues before they escalate
- Enhanced safety: Prevents potential hazards associated with motor failures.
- Remote monitoring: Allows for remote monitoring of motor health and fault status.

- Data-driven insights: Provides valuable data for analyzing motor performance and identifying potential failure modes.

7. APPLICATION

- Industrial Automation
- Automotive Industry
- Renewable Energy
- Aerospace & Defence
- Medical Devices

8. FUTURESCOPE:

Advanced fault detection algorithms: Explore more sophisticated machine learning algorithms for improved fault detection accuracy. Predictive maintenance: Utilize data analytics to predict potential failures and schedule preventive maintenance. Integration with other systems: Integrate the system with other IoT devices or control systems for comprehensive monitoring and control. Wireless communication: Explore alternative wireless communication technologies for improved connectivity and range. Energy efficiency: Optimize the system's power consumption to reduce energy costs. Customization: Allow for customization of the system to meet specific motor types and operating conditions.

9. CONCLUSION

This system offers a comprehensive solution for monitoring the health of a DC BLDC motor. By combining the power of the ESP32 microcontroller, various sensors, and a fault detection algorithm, it provides a reliable and efficient means of preventing unexpected failures. The integration with Blynk enables real-time monitoring and remote access, making it a valuable tool for maintenance and troubleshooting. One of the key advantages of this system is its cost-effectiveness. The ESP32 is a relatively inexpensive microcontroller, and the sensors used can be readily available. Additionally, the fault detection algorithm can be implemented using open-source software or custom-developed code, further reducing costs. Another benefit of this system is its flexibility. The fault detection algorithm can be easily modified or adapted to meet specific requirements, allowing for customization to different motor applications and operating conditions. Furthermore, the integration with Blynk provides a versatile platform for data visualization and notification, enabling users to tailor the system to their preferences and needs.

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