*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 10 October 2022

Fault analysis of PMDC motors

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Abstract

Permanent magnet DC brush motors are one of the most important tools used in the current world when it comes to the mechanical industry. To ensure good results and high efficiency these industries need to keep these motors well maintained by being able to detect when a motor's efficiency is lowering and accordingly rectify any issue. This research focuses on creating a fault detection system for PMDC brush motors which can alert one of a potential fall in efficiency or changing parameters of a motor so that they can accordingly control it in order to maintain the best possible results. In this research paper, data of the temperature, current, voltage, and speed of a pmdc motor was collected and based on this data a predictive model was created which uses other factors to predict if and when a change in a specific parameter is detected.

1. **Introduction:**

As we all know, an electric motor is essential in every industry in automation or robotics, and a motor is a common tool with a wide range of applications.
Choosing a motor for a system is a critical step in the overall system design. Many factors must be considered, including efficiency, cost, reliability, power density, technology maturity, and controllability.

Because of heavy duty cycles, installation, a poor working environment, and improper excitation, these machines are more likely to fail after installation in a machine or equipment.
as well as manufacturing factors, etc. With rising demands for efficiency and dependability, the field of fault diagnosis in motors is becoming more important.[1]

Fig.1- electric motors in industry [2]

So, in this paper, we will analyze how to check motor efficiency, torque, current, voltage, and lifecycle as a function of rotation per minute.

PMDC brush motor systems are systems used across various industries to convert other forms of energy into mechanical energy. These systems are used in the toy industries, automobiles, large factory machinery, etc. Overall, these motors are used to control motion in various systems across industries as they produce a high torque at low speeds.

Their working and processes involved in producing torque is based on the principle of Fleming's left-hand rule. The motor consists of a permanent magnet and current carrying coils in loops called the armature. According to Fleming's left-hand rule, a force is produced perpendicular to the plane on which the magnetic field vector and current vector lies. As visible in the diagram below, all mentioned fields act at a 90-degree angle to each other. The formula for the torque that is produced is given by the following equation: Tg= (60.Eb.Ia)/(2N) where Tg is the torque produced, Eb is the back EMF (EMF generated due to rotation of coil), Ia is the armature's current, and N is the speed of rotation.
The brushes maintain the exact position of these three fields so that there is a uniform motion, and the motor doesn't turn in both directions.

As mentioned previously, the PMDC motor has applications in various industries. It is primarily used in areas where any form of motion or rotation at a small scale is required but doesn't need to have very effective and precise control. A few advantages of the PMDC motors that make them suitable for their tasks are that they are very small in size so convenient to use in many systems. They are significantly cheaper to produce than a brushless direct current motor and are also very energy efficient. However, the motor may also cause some trouble once used frequently. Demagnetization of the poles due to excessive heat produced by the motor may lead to poor performance after many uses. It is also only used in areas where effective and precise control is required because the torque and speed can't be controlled externally given the fact that it uses permanent magnets, and the magnets must be changed to vary affected factors.

Literature Survey:

"In this paper, "Estimation of Load Disturbance Torque for DC Motor Drive Systems Under Robustness and Sensitivity Consideration," author Danny Grignion presents methods for measuring disturbances in torque of a DC motor system. These designs have the advantage of ensuring robust estimation in the presence of model uncertainties and/or noise. These estimation schemes are shown to be capable of estimating both constant and nearly constant disturbance torques. The nominal plant model is expanded to include uncertainties in order to design the observers. Several cases for the observer's design are presented. Each case is tested on a real system with varying degrees of model uncertainty. [12]

"Fault detection and identification (FDI) of electrical motors is critical to ensuring smooth operation of several industrial systems," according to the paper "Data-Driven Approaches for Diagnosis of Incipient Faults in DC Motors." When faults are detected and diagnosed at an early stage, corrective actions can be taken to reduce the severity of the fault. However, FDI of incipient faults has proven elusive to traditional fault diagnosis methods. With recent advances in statistical machine learning, new methods for FDI are being proposed. In this paper, we use three machine learning tools (support vector machine, convolutional, and recurrent networks) to address the problem of FDI of incipient faults." [13]

V. A. Maldonado-Ruelas develops a testbed for the evaluation of fault diagnosis algorithms for electric vehicles in his paper "In-wheel brushless DC motor test-bed for control and fault detection. "This paper describes the design and development of an in-wheel brushless DC (BLDC) motor test-bed, as well as the BLDC motor modification to introduce different electric fault scenarios. The BLDC motor was rewound to introduce short and open circuit stator faults.[14]

IThe author Letcia Maria Sathler Vianna's paper "Fault Detection in Brushless DC Motor via Particle Filter" seeks to determine whether a new method for detecting fault of a BLDC motor using a non-linear factor is effective by comparing it to a proven method that uses a linear factor to detect fault. The problem of brushless dc motor (BLDC) fault detection is addressed in this article. The fault under investigation is a power supply interruption in one of the stator phases. This problem has already been solved using various parameter estimation techniques, such as the Least Squares Estimator and the Recursive Least Squares Estimator, which estimate the parameters of a linear model related to the fault, allowing for fault detection." [15]

Deepesh Agarwal examines a method of fault detection in a motor using Finite Element Analysis (FEA) based motor models in his paper "Fault Diagnosis and Degradation Analysis of PMDC motors using FEA based models."

In Electric Vehicles, electric motors are solely responsible for producing traction power (EVs). Motor health monitoring is critical to ensuring robust vehicle performance, adhering to safety requirements, and avoiding further catastrophic consequences leading to powertrain failure. Fault diagnosis and degradation analysis enable the detection of motor abnormalities at an earlier stage, allowing appropriate preventive measures to be implemented to limit the severity of faults. Motor simulation studies aid in understanding the nature of various incipient faults without the need for costly experimentation. Furthermore, several early faulty conditions are difficult to introduce in time-limited experiments. Given the benefits of simulations, we use Finite Element Analysis (FEA)-based motor models for fault diagnosis and degradation analysis. Because of the detailed simulations. Since the detailed simulations are time-consuming, we generate surrogate current data using that obtained from simulations. We employ support vector machines for fault classification using features obtained from current data. The robustness of the proposed framework to measurement noise is also analyzed." [16]

The author Zhonghai Li analyses different fault conditions in the simulation of a BLDC motor in the paper "Simulation and fault diagnosis for bldcm," and they use an algorithm to perform fault diagnosis using the proposed fault model.

"BLDCM (Brushless Direct Current Motor) faults are difficult to avoid and can have serious consequences." FDD (fault detection and diagnosis) that is effective can improve motor reliability while avoiding costly maintenance. As a result, early examination and diagnosis of the motor common fault could effectively prevent the disaster from occurring, which is extremely important. Create a BLDCM simulation model with the help of finite element software Maxwell and Simplorer. Inject fault by changing the motor parameters to establish the fault model. Make the EMD decomposition with the model's stator phase current to obtain a series of intrinsic mode functions, then apply the SPWVD time-frequency analysis to the IMF to obtain the time-frequency characteristic under different fault conditions. Summarize the change law of time-frequency characteristics that vary with fault degree using multi-group data. Finally, an intelligent optimization algorithm CPSO (Chaotic mutation-based Particle Swarm Optimization) is used to perform fault diagnosis for the motor, which is capable of identifying both fault location and fault severity. The consistency of simulation results and experimental analysis validated the simulation model and diagnosis method."[17]

In the paper "Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review", The author S. Nandi looks at the various methods of fault detection that have recently been adopted by analyzing factors such as speed, temperature, chemical analysis, etc.

"Recently, research has picked up a fervent pace in the area of fault diagnosis of electrical machines. The manufacturers and users of these drives are now keen to include diagnostic features in the software to improve scalability and reliability. Apart from locating specific harmonic components in the line current (popularly known as motor current signature analysis), other signals, such as speed, torque, noise, vibration etc., are also explored for their frequency contents. Sometimes, altogether different techniques, such as thermal measurements, chemical analysis, etc., are also employed to find out the nature and the degree of the fault. In addition, human involvement in the actual fault detection decision making is slowly being replaced by automated tools, such as expert systems, neural networks, fuzzy-logic-based systems; to name a few. It is indeed evident that this area is vast in scope. Hence, keeping in mind the need for future research, a review paper describing different types of faults and the signatures they generate, and their diagnostics' schemes will not be entirely out of place. Such a review helps to avoid repetition of past work and gives a bird's eye view to a new researcher in this area." [18]

Proposed System:

In our project, we connected a current sensor and a voltage sensor to measure the voltage and current. where we have connected Motor as an input device to check and display all PMDC motor parameters like motor's temperature, current, voltage, and speed. and used to create a predictive model that uses other factors to predict when a change in a specific parameter is detected.

Why Parameter are important while selecting of motor:

A rotary motor's purpose is to provide a desired rotational output speed while overcoming the various rotational loads that resist that rotational output (Torque).

Thus, the two primary performance factors in properly selecting a motor for a specific application or use are speed and torque.

We use the relationship between a motor's speed, torque, and output power to select the right motor for the application[3].

1. Torque: The torque output of a motor is the amount of rotational force produced by the motor. A small electric motor's torque is commonly measured in inch pounds (in-lbs), Newton meters (N-m), or other directly converted units of measurement.[3]
2. Power: A motor's mechanical output power is defined as its output speed multiplied by its output torque and is typically measured in Watts (W) or horsepower (hp).
3. Speed: A motor's speed is defined as the rate at which it rotates. An electric motor's speed is measured in revolutions per minute, or RPM

Relation between Speed and Torque:

Based on the equation: The output power of a motor establishes the speed and torque performance bounds of a motor.

Power (P) = Speed (n) x Torque (M)

Calculating Mechanical Power Requirement:

For example, assume that it is necessary to determine the power required to drive a torque load of 4 oz-in at a speed of 150 RPM.

To convert power in watts we need to multiplied by conversion factor.

Speed Units	Torque Units	Conversion Factor
RPM	oz-in	0.00074
rad/sec	oz-in	0.0071
RPM	In- lb.	0.0118
rad/sec	In- lb.	0.1130

So for power= 4*150*0.00074 =0.44 watts

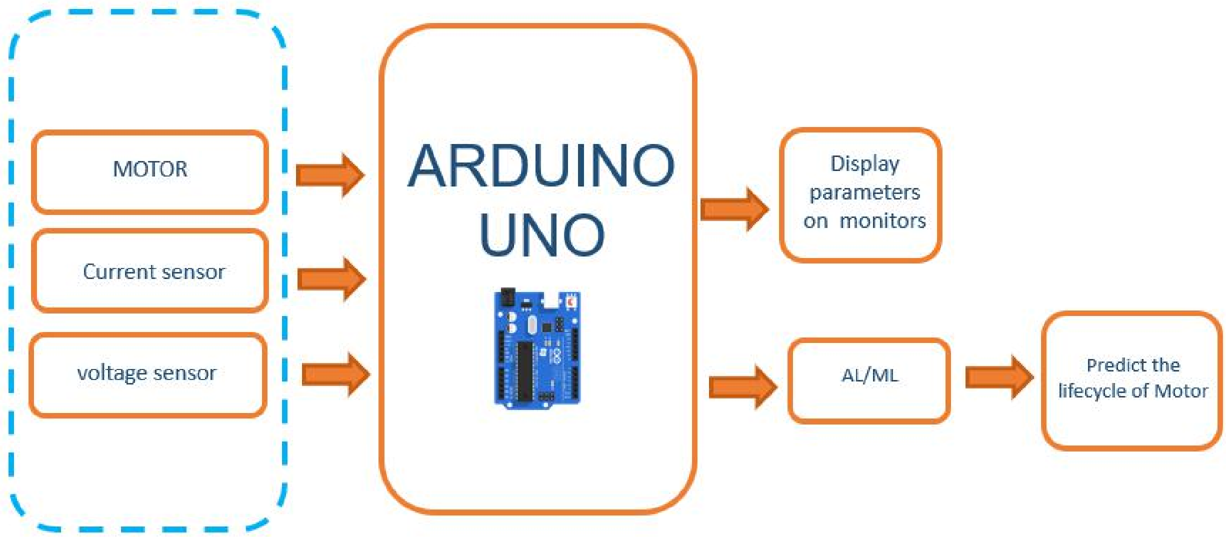
In our project, we used a PMDC motor with torque and speed that produces __ power.

Need to check motor Efficiency and lifecycle:

When new motors and generators are installed, the electrical system should be in excellent condition. Furthermore, rotating machine manufacturers have worked hard to improve the quality of their products. Nonetheless, even today, motors and generators are subject to a variety of conditions that can cause them to fail, such as mechanical damage, vibration, excessive heat or cold, dirt, oil, corrosive vapours, moisture from processes, or simply air humidity. These factors are present to varying degrees, and when combined with the electrical stresses that exist, they create a harsh environment for daily operation.[4]

Moisture and foreign matter penetrate the surfaces of insulation as pin holes or cracks form, providing a low resistance path for leakage current. Once started, the various enemies tend to help each other, allowing excessive current to pass through the insulation. When equipment is flooded, the drop in insulation resistance can be abrupt. If tested on a regular basis, it usually drops gradually, giving plenty of warning. Such tests allow for planned reconditioning prior to service failure. A motor with poor insulation, for example, may not only be dangerous to touch when voltage is applied, but it may also burn out if not tested on a regular basis.[4]

Block Diagram



In our project, we used current and voltage sensors in conjunction with an Arduino microcontroller.

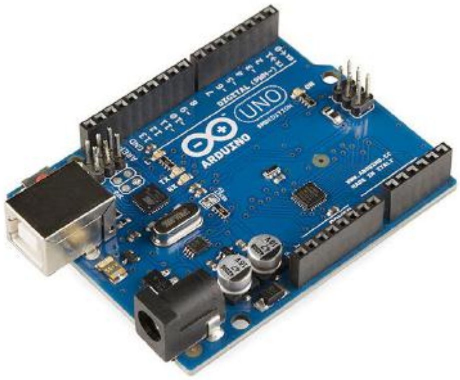
We detect and convert current in measuring voltage using a current sensor, and we check voltage data using a voltage sensor.

If the voltage data exceeds a certain threshold, an alert is generated, and all of the relevant parameters are displayed on the system.

Using artificial intelligence and machine learning, we created fuzzy logic to predict the Lifecycle of motor.

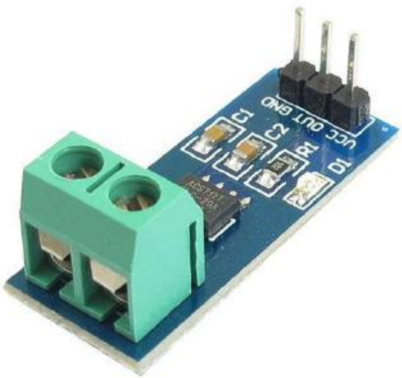
Hardware Description:

1. Arduino UNO:The ATmega328P-based Arduino UNO is a microcontroller board. It has 14 digital I/O pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a ceramic resonator operating at 16 MHz, a USB connection, a power jack, an ICSP header, and a reset button. It comes with everything you need to support the microcontroller; simply connect it to a computer via USB or power it via an AC-to-DC adapter or battery to get started.[5]



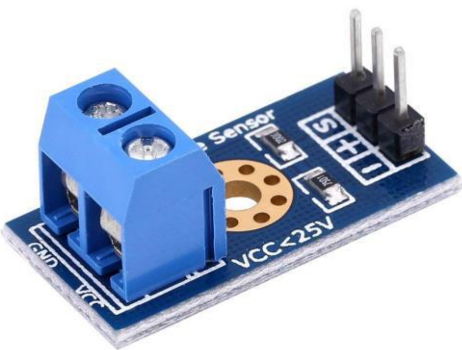
Fig[6]

2. Current sensor:
3. A current sensor is a device that detects and converts current to a measurable output voltage proportional to the current flowing through the measured path. There are many different types of sensors, and each one is designed for a specific current range and environmental condition.[7][10]



Voltage sensor:

A voltage sensor is a sensor that measures and calculates the amount of voltage in an object. Voltage sensors can detect either AC or DC voltage levels. This sensor's input is voltage, and its output is a switch, analogue voltage signal, current signal, or audible signal.[8][11]



4. PMDC motor: a motor which has permanent magnet pole.[9]

Integration and testing:

1. We started with a multimeter, which produced the same results as the current and voltage sensors.
2. We calculated various parameters using a current sensor and a voltage sensor.
3. We are calculating the No load current, Starting current, Full load current, Maximum, Minimum, and Average current of the motor using a current sensor.
4. We calculated starting voltage, capacitor voltage, and generated voltage using a voltage sensor.
5. Data collection is used to analyse trends over time.
6. As a result, we save all of the data on an Excel sheet.
7. We developed fuzzy logic to predict motor working cycles using artificial and machine learning.
8. The graph represents the current and voltage ratio while the testing voltage ranges from 11 to 12 V. The graph is predicated by AI/ML and the detecting value is decreasing by threshold values.

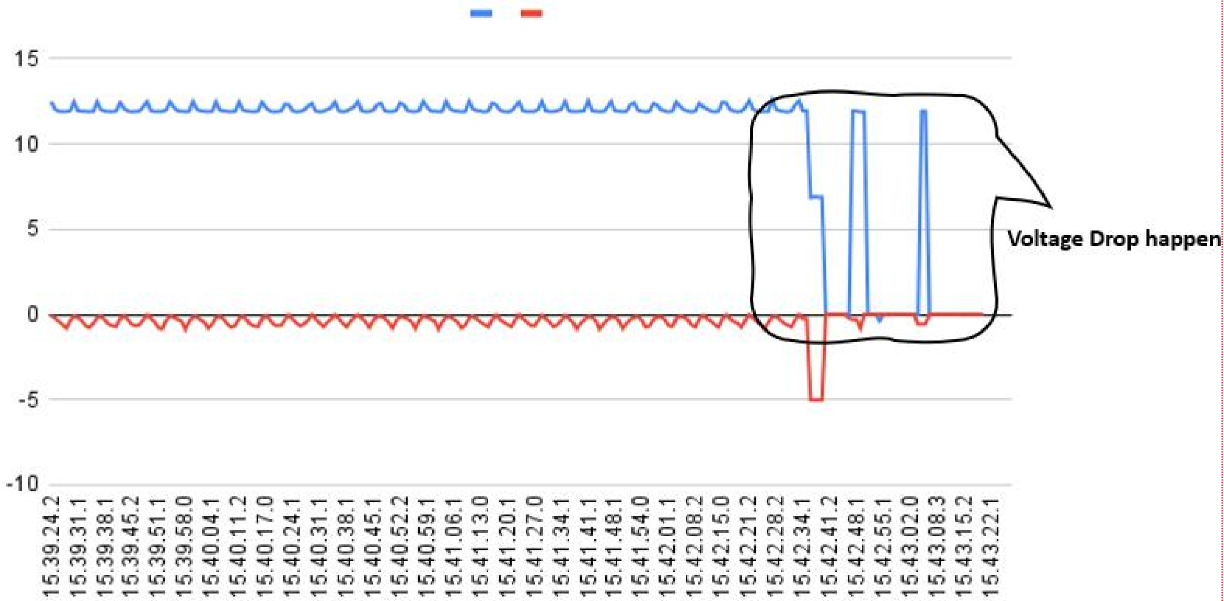


Fig1- Graph representation

9. Voltage drops during testing because the motor does not receive enough torque.
10. In our project, 9.8% of the voltage dropped, causing problems with the motor.
11. The amount of voltage drop required to damage a motor is highly dependent on the load on the motor.

Conclusion:

with this prototype we have concluded that when motor is working with full load data is work properly but if something wrong happen with motor it will not give sufficient torque.so data from testing is essential for determining motor quality and will help the PMDC motor maintenance plan.

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