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Artificial Intelligence and Iot Based Traction Motor Drive Condition Motoring In Hybrid Electric Vehicle

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ABSTRACT

The traction motor drive system holds a crucial role within electric vehicles (EVs), necessitating an efficient and dependable design to deliver optimal speed and torque across a wide operational spectrum. Ensuring safe and precise control of the motor drive is of paramount importance. This project focuses on establishing an AI-driven approach for monitoring the condition of the traction motor drive in hybrid electric vehicles.The proposed initiative revolves around creating a sensor-based configuration capable of efficiently gathering data related to motor vibrations and temperature fluctuations under varying vehicle driving conditions. Leveraging a trained machine learning model, anomalies in the traction motor's behavior during vehicle motion are identified. The dataset, obtained through sensor nodes, is partitioned into training and testing subsets. By training the machine learning model on this dataset, it becomes equipped to perform real-time monitoring of the traction motor drive, promptly detecting any irregularities that arise. Upon the identification of abnormalities or insufficient power, immediate notifications are dispatched to the operator, prompting potential intervention. Furthermore, the vehicle's drive train can be automatically adjusted in response. An IoT-based system is established to facilitate data collection and transmission to a cloud-based backend for the purpose of real-time visualization, anomaly monitoring, and generating alerts.

***Keywords:** .Machine learning, Train test split, Traction drive, Switchover, IOT, Abnormalities etc*.

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I. INTRODUCTION

The traction motor drive system holds vital importance within electric vehicles (EVs), functioning as a pivotal component. The efficiency and dependability of the traction motor are paramount, given its role in delivering both speed and torque across a broad operational spectrum while ensuring precise and secure motor drive control. In order to avert potential abnormalities in the traction motor's functioning, enhancing reliability and operational efficiency, coupled with prompt notifications for early warnings, is highly desirable.Motor vibration, current, and temperature are three parameters that have been extensively studied and widely acknowledged for their effectiveness in detecting motor failures arising from electrical and mechanical faults. These parameters collectively contribute to a comprehensive understanding of the motor's health, enabling timely interventions and preemptive measures.

As per the investigation conducted by the Institution of Electrical and Electronic Engineers (IEEE), bearing-related issues account for 44% of motor faults, while stator-related problems contribute to 24%. Among the primary mechanical failures observed in motors, mechanical imbalance, rolling, and bearing malfunctions are predominant, primarily caused by sustained stress on these components leading to significant breakdowns. Various factors, including inadequate lubrication, improper installation, contamination, and corrosion, frequently play a role in the occurrence of rolling and bearing faults.

Employing a vibration sensor and current sensor enables the identification of irregular bearing operation, characterized by heightened vibrations, and unbalanced shaft current resulting from flux disturbances arising from rotor eccentricities. Furthermore, bearing failure leads to an elevated temperature that surpasses the motor's designated load temperature. This integration of sensors provides a comprehensive approach to monitoring and diagnosing motor issues, facilitating the early detection of problems and preventing potential catastrophic failures.

This paper deals with the development of the Traction motor drive condition monitoring in hybrid electric vehicle using machine learning and IOT. Dataset of the traction motor drive is collected by setting up a test bench to monitor the various parameters including the vibrations, temperature, speed power etc to determine the abnormalities in the traction motor. The machine learning model is trained on the collected dataset which is capable of determining the abnormalities and the power deficiency form the electric drive train. The IOT based system is used to alert the operator and service centres and automatic switch over in hybrid vehicles is suggested by the medium of this research topic.

II. LITERATURE REVIEW

Prior to initiating the research, a comprehensive examination of the designated project domain is imperative to gain a profound understanding of the challenges encountered and potential remedies thereof. To establish the problem statement and devise viable strategies, an extensive review of research papers was undertaken. Noteworthy contributions from this body of literature are outlined in the subsequent literature review section.

In the work titled "IoT platform for condition monitoring of induction motors" [9], the utilization of various elements that enable continuous and controlled surveillance leads to a substantial enhancement in productivity. Consistent monitoring of machinery, coupled with alert generation and access to data for predictive maintenance, contributes to effective operational oversight. Employing internet-based resources, induction motors are subject to efficient and continuous monitoring, ensuring their optimal performance.

Kunthong et al., in their paper titled "IoT-based Traction Motor Drive Condition Monitoring in Electric Vehicles: Part 1" [10], address the management of traction motor drive condition in electric vehicles through the implementation of remote IoT technology. The paper outlines the design and experimentation of a model utilizing an ESP8266 microcontroller module to obtain and assess the engine's operational status.

Prakash, Chetna, and Sanjeev Thakur explore a "Smart Shut-Down and Recovery Mechanism for Industrial Machinery" in their contribution to the 2018 8th International Conference on Cloud Computing, Data Science & Engineering (Confluence) [11]. Within industrial contexts, continuous monitoring of every motor is imperative to establish a foundation for predictive maintenance practices. The integration of a backup machine during disruptions proves instrumental in minimizing losses and subsequently enhancing reliability.

Şen and Basri Kul present a study on "Wireless IM Monitoring Based on IoT" in the 2017 XXVI International Scientific Conference Electronics (ET) [12]. This approach ensures that the manufacturing process remains unhindered, allowing essential maintenance or replacement tasks to be executed with minimal disruption. The research not only offers insights into creating mathematical models but also empowers the CMS administrator to establish a comprehensive motor maintenance strategy.The experiment showed that the system was able to successfully segregate waste into the three categories. The authors believe that this system could be used to improve waste management in urban areas.

Xue, Xin, V. Sundararajan, and Wallace P. Brithinee present a study titled "Utilizing Wireless Sensor Networks for Monitoring Three-Phase Induction Motor Condition" in the 2007 Electrical Manufacturing Expo [13]. The prevalent approach employed for detecting faults in large-scale three-phase induction motors involves measuring the motor's current consumption and analyzing the signal spectrum. Implementing this methodology reduces the downtime required for machine repairs, thereby ensuring sustained profitability for companies.

Andrew Chater and Steve Mitchell presented a study titled "Multi-Technology Condition Monitoring for Traction Motors in Service" at the IET Railway Condition Monitoring conference in 2008 [5]. The primary objective of the 'control' aspect was to quantify the external vibration and stress wave levels generated in comparison to the gearbox, traction motor, and internal motor metrics. To achieve this, bullet cameras were affixed to the train's underframe, positioned internally to the traction motor. Custom sensors were developed by PCMS and affixed to the brushes, boasting a frequency response profile meticulously tailored for detecting vibration, temperature, and ultrasonic signals. The compact size of the accelerometers allowed for their mounting at each brush position encircling the commutator. For electrical isolation, a thin section of bakelite separated the sensors from the brushes, ensuring proper functioning.

Chung Ming Leung and Siu Wing conducted a study titled "Magnetoelectric Passive Current Sensors for Wireless Condition Monitoring of Train Traction Systems," which was published in the IEEE Sensors Journal, Volume 14, Issue 12, 2014 [4]. The wireless condition monitoring system was implemented during a field study on Hong Kong's East Rail Line. In this study, a total of four pairs of magnetoelectric passive current sensors and single-channel wireless transmitters were strategically placed. These installations were positioned on and in proximity to the electric cables of four electric motor drives situated beneath the 2nd, 5th, 8th, and 11th cars of a 12-car mainline train. To facilitate real-time monitoring of the current signatures from the train's traction system, a four-channel wireless receiver was stationed in the train's driver cab. This setup enabled continuous observation of the current signatures of the four electric motor drives, both during steady-state operation and acceleration conditions. The recorded current signatures underwent post-processing to derive valuable information, including the distribution of harmonic-to-fundamental current ratios, total harmonic distortions, power factors, and frequency spectra.

From the literature review studied the following literature gap can be deduced. The brief literature review has been studied to determine the drawbacks of the currently existing system as well as to understand the scope of the project. However the following research gaps have been determined in the literature review.

The current approach uses just sensor based approach to determine of monitor the traction drive in electric vehicles. The data from the sensors can vary over the external atmospheric conditions and needs to be calibrated with compensation offset for accurate results which is difficult for on road conditions

Most of the research work is just focused on the development of IOT based framework for monitoring of the traction motor monitoring. However rather then just monitoring, a framework is required for to assure the reliability of data with least calibration of sensors

This motivates us to develop the system which can :

- Traction motor faults from bearing comprise of the majority of the motor failures in EV drives
- The failures in Traction motor are due to mechanical imbalance, rolling and bearings which can be monitored in advance.
- The motor power consumption determination can also be used to predict failure

III. METHODLOGY

The entire approach towards the project is divided into number of steps to minimize the errors at the end . The methodology to be implemented to carry the project is:

- Dataset collection: The dataset is collected from the sensor nodes and test bench setup. Test bench for electric vehicle drive train comprising of 1HP BLDC Motor is setup to collect the dataset of temperature, speed, power, battery consumption, vibrations etc
- Dataset pre-processing: The dataset is labelled in this phase. The unwanted dataset is removed which is a part of the pre-processing
- Training the model: Machine learning approach is used to train a classifier model on the collected dataset. The classifier will take the set of input live readings and output the abnormality type, power deficiency , and label for the same. The model is trained using the collected dataset and then performance evaluation is done to calculate the reliability of the model before it is deployed.
- Traction motor drive monitoring: Once the machine learning model is ready, it is deployed in real-time for the monitoring of the traction motor drive. The system consist of experimental setup with traction motor drive and loading system to load the drive train externally. The sensor nodes in the smart traction motor monitor the motor condition, feed it to the trained neural network for detection of the abnormalities and check for the power deficiency under the load. The Single board computer raspberry pi is used to monitor the data from the sensors nodes and deploy the trained machine learning model
- IOT based notificaitoon and realtime monitoring system- In this phase the iot based system is developed which will push the data collected to the cloud so that can be monitored using an app. The system will also send notifications regarding the abnormalities and also suggest switch over if power falls short.
- Hardware and schematic design: In this phase the hardware and the schematic of the project is designed. The PCB layout is finalized
  - Assembly and programming
  - Testing and optimization
  - Conclusion

IV. WORKING PRINCIPLE

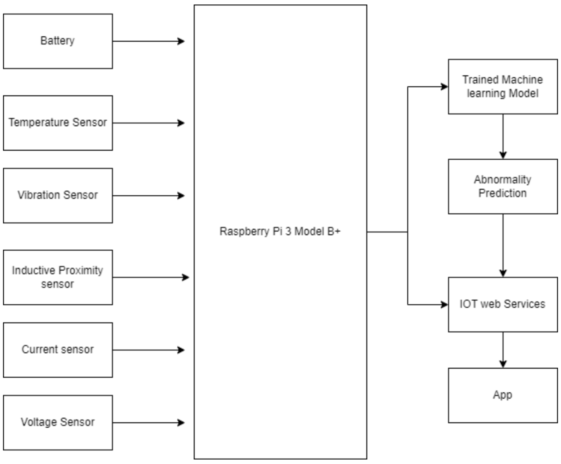

Fig 1.Block Diagram of the system

As shown in the block diagram the system consist of the hardware which is capable of running the machine learning algorithms to monitor the condition of the traction drive motor. The Sensor nodes connected to the hardware collect the data from the traction motor drive train and feed it to the trained machine learning model deployed using the dataset collected on the test bench. The machine learning approach monitors the data from the different sensor nodes in realtime and predicts the abnormalities, failure or power deficiency on the electric drive train. If the abnormality is detected the IOT based system will be used to alert the operator as well as the maintenance service station regiarding the same and automatically the service will be scheduled depending on the level of the abnormality. If the power deficiency in the traction drive train is detected the automatic switch over will be suggested to overcome the power deficiency in hybrid vehicle.

V. HARDWARE AND SOFTWARE ASSEMBLY

The following hardware is used for the implementation of the system:

1. 1 HP BLDC Electric Vehicle motor
2. MEMS Vibration sensor
3. Inductive Proximity Sensor
4. Temperature sensor
5. Current Sensor
6. Voltage sensor
7. Loading arrangement
8. Battery
9. Raspberry Pi Single Board computer

The following software is used:

1. Anaconda navigator
2. Scikit Learn
3. Python 3.8
4. WAMP server
5. Android Studio

The figure below the shows the machine learning flow implemented in the project to make the project more accurate:

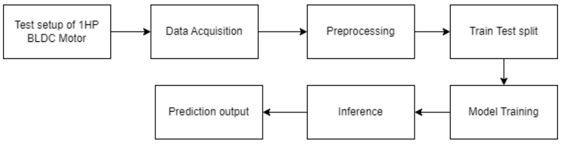

Fig.2 Machine learning flow diagram

The steps involved are:

- Dataset collection
- Dataset Preprocessing
- Train Test Split
- Training the model on collected dataset
- Deployment

VI. HARDWARE DESIGN

The hardware development involves schematic and PCB development using Easy EDA software. The hardware is designed using the Easy EDA schematic capture and then the PCB s are fabricated to make the complete working of the project.

The printed circuit board (PCB) acts as a linchpin for almost all of today's modern electronics. If device needs to do some sort of computation-such as is the case even with the simple digital clock. Chances are there is the PCB inside of it. PCBs bring electronics to life by routing electrical signals where they need to go to satisfy all of the device's electronic requirements

The figure below shows the schematic diagram of the project.

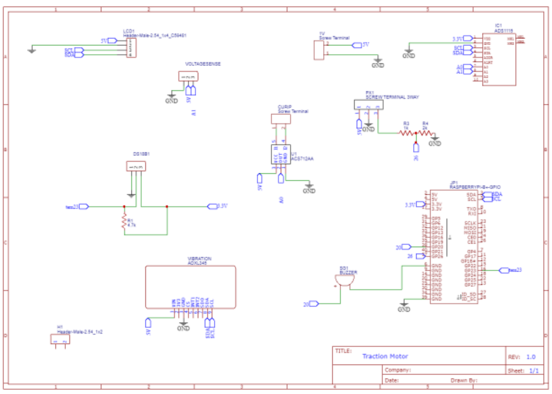

Fig 2.Schematic Circuit Diagram

Once the schematic diagram is ready, the PCB fabrication layout is as shown below:

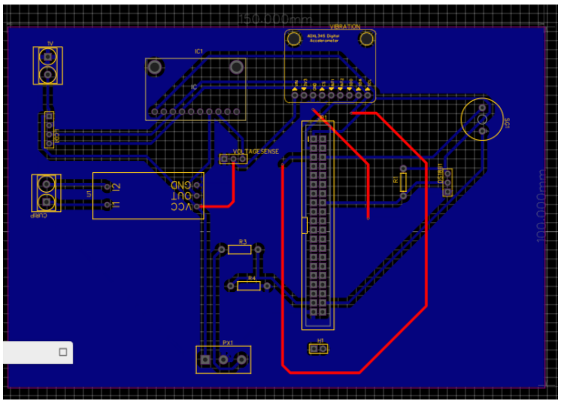

Fig 3.PCB Fabrication Layout

VII. RESULTS AND DISCUSSION

In this section the results of the approach are discussed. This mainly deals with the collection of the data from the machine learning test bench for determining of reading the various parameters for the electric motor and then training the machine learning model for prediction of the cause of the failure or errors.

The dataset was collected from the developed test bench and the machine learning model training was performed.

Three Different Algorithms were used,

- SVM
- KNN
- Decision Tree

The dataset collected and the distribution of the dataset is as shown:

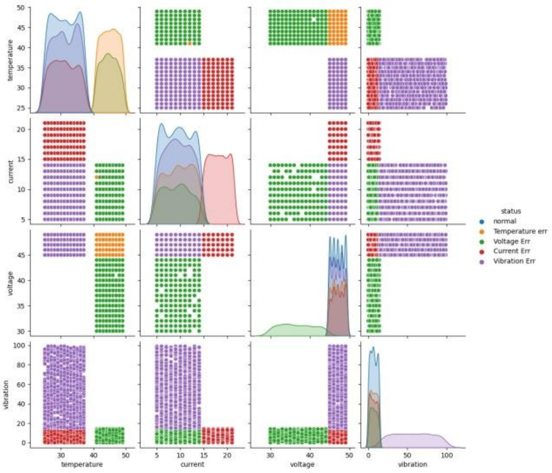

Fig 4.Distribution of the Dataset

The accuracy of the prediction is as shown in the table below.

Sl. No	Algorithm	Accuracy
1	SVM	0.976031957301465
2	KNN	0.986684407723036
3	Random Forest Classifier	1.0

Table 1. Developed IOT application

The different Performance parameters are as shown below.

	precision	recall	f1-score	support
Current Err	1.00	0.96	0.98	117
Temperature err	0.96	1.00	0.98	138
Vibration Err	1.00	0.96	0.98	181
Voltage Err	1.00	0.93	0.96	87
normal	0.95	1.00	0.97	228
accuracy			0.98	751
macro avg	0.98	0.97	0.98	751
weighted avg	0.98	0.98	0.98	751

Fig 4.Performance Parameters of SVM

	precision	recall	f1-score	support
Current Err	1.00	0.97	0.98	117
Temperature err	0.99	0.99	0.99	138
Vibration Err	1.00	0.98	0.99	181
Voltage Err	0.98	0.99	0.98	87
normal	0.97	1.00	0.98	228
accuracy			0.99	751
macro avg	0.99	0.98	0.99	751
weighted avg	0.99	0.99	0.99	751

Fig 5.Performance Parameters of KNN

	precision	recall	f1-score	support
Current Err	1.00	1.00	1.00	117
Temperature err	1.00	1.00	1.00	138
Vibration Err	1.00	1.00	1.00	181
Voltage Err	1.00	1.00	1.00	87
normal	1.00	1.00	1.00	228
accuracy			1.00	751
macro avg	1.00	1.00	1.00	751
weighted avg	1.00	1.00	1.00	751

Fig 6.Performance Parameters of RFC

From the above performance parameters we can conclude that the Random Forest classifier gives accurate results making it the best choice for implementation on the realworld data.

The IOT Application Developed is as shown below.

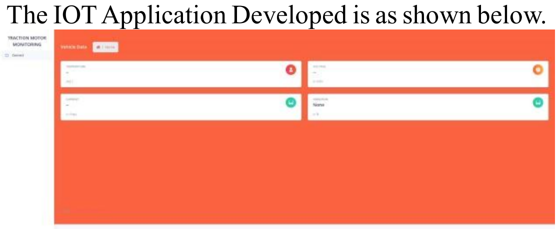

Fig 7. Developed IOT application

VIII. CONCLUSION

The paper discusses the uses of machine learning to determine and monitor the traction motor. This research work proposes the software & hardware design and measurement results of the internet of things and AI based traction motor monitoring system for electric vehicles. temperature sensor, vibration sensor, load sensor, and voltage sensor used to monitor the performance of the components. The system is implemented to sense the parameter of the electric motor and battery of the electric vehicles. By using the concept of the internet of things data will send to the connected device by which one can get all information about components. Using this information one can get an idea about the maintenance of the components. The system is expected to improve the accuracy in prediction of the failure of the system using machine learning and AI and also provide with a switch over suggestion in hybrid drive trains. Since the system uses ML and AI it is more accurate and can predict the failure in advance.

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