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IoT Based Nano Device for Monitoring Induction Motor for Electric Vehicle Applications

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Abstract

With the growing emphasis on clean energy and connectivity, electric vehicles (EVs) are emerging as a vital player in the power sector, especially in the implementation of the smart grid, enabling the vehicles to communicate with the grid. Banning the sale of fossil-fuel vehicles is essential in reducing health risks from air pollutants like diesel PM10s and nitrogen oxides and achieving global greenhouse gas reduction targets stipulated by international agreements such as the Kyoto Protocol and Paris Agreement. The use of clean energy in modern vehicles allows their motors to function independently, making them distinct from fossil-fuel-powered vehicles. To comply with various bans, the automotive industry is endeavoring to create EVs, which some see as a possible revenue stream in a declining market. Governments find it appealing to prohibit fossil-fuel-powered vehicles since it's an easier compliance target than implementing a carbon tax or phasing out fossil fuels. Utilizing simulation, we can acquire the induction motor's real-time criteria, resulting in the motor's enhanced operational efficiency and the industry's development. The proposed controller device is miniature/nano as it is made of power electronic components. The dependable technology provided by the electric locomotive benefits both the power and locomotive industries. The green vehicle fosters the development of alternative domestic power sources and assists the grid by providing ancillary services. The future potential of EVs is enormous, necessitating independent monitoring of their motors to improve proficiency in IoT (Internet of Things) implementation.

Keywords

Induction motor, Internet of things, Power electronic, Nano device

Introduction

The research project investigating the Modeling and Performance Analysis of EV Power Drivetrain has a clear goal of enhancing the existing system by improving the understanding of motor simulation, fault identification through continuous monitoring, and condition checking to rectify faults and increase motor efficiency. The global push towards full electrification means that EVs are anticipated to overtake fossil fuel vehicles as the primary vehicle type in the automotive industry [1]. This is due to the numerous benefits of electric cars, including reducing health risks from air pollutants and meeting international greenhouse gas reduction targets. Governments, in particular, are eager to ban fossil fuel vehicles as it is a simpler compliance target to meet. With the market for traditional cars in decline, the automotive industry is working towards introducing EVs as a source of revenue.

Recent research revealed that the manufacturing emissions of batteries for new EVs are much lower than previously thought, in addition the lifespan of lithium batteries remains much longer than expected [2]. EVs are cleaner and more energy-efficient than internal combustion cars powered by petrol or diesel, and they play an important role in the power sector, particularly in the application of the smart grid. EVs function as smart automobiles through grid communication and provide an alternate power source for domestic use and auxiliary services to the grid. They also help in combining intermittent resources for automobile charging, providing ease of charging at home, and requiring less maintenance [3].

Since modern vehicles use clean energy, their motors are independent of each other, highlighting the need to monitor the motors individually for better proficiency in EVs. Electric cars have enormous future potential and offer new opportunities for charging banks and other areas, including homes and cities [4-6]. As a result, the research work aims to monitor the health of an Induction motor in an EV by maintaining high efficiency, constant monitoring, optimal use of power, identifying faults, and conditioning hardware [7]. By doing so, this research aims to contribute to the development of more efficient and reliable electric cars that can drive the transition towards a greener and more sustainable transportation system.

The research project on Modeling and Performance Analysis of EV Power Drivetrain aims to improve the existing system by enhancing motor simulation, identifying faults, and maintaining high efficiency of the induction motor in an EV [8]. The need to transition towards EVs has become more pressing due to the increasing health risks from air pollutants and meeting international greenhouse gas reduction targets. Governments and the automotive industry are keen to adapt to bans on fossil fuel vehicles and look to electric cars as a source of revenue. EVs are energy-efficient, cleaner, and offer new opportunities for charging banks and other areas [9]. By investing in research and improving the performance of electric cars, we can help to establish a cleaner and more sustainable transportation system.

EVs have gained popularity as a sustainable mode of transportation, but their limited range is a major challenge that needs to be addressed. The battery capacity significantly impacts the range, and it is also the most expensive component of EVs. However, there are other design parameters that can be optimized to enhance the range of EVs [10-12]. These include weight reduction, aerodynamic drag coefficient minimization, and motor size optimization. In addition, driver behavior can also influence the range of EVs. To assess the effect of these factors on range, simulations were developed using real driving cycles to improve accuracy. By optimizing these parameters, it is possible to improve the range of EVs and enhance their acceptance among consumers.

In industrial applications, induction motors are commonly used, and monitoring and controlling their parameters are crucial for reliable operation. The study focuses on remote monitoring of a three-phase induction motor using IoT [13-15]. The motor's temperature, voltage, and current are monitored using sensors and transducers. The data is sent to a processing unit that displays the parameters on a server, providing manual and automatic control methods to start or stop the induction motor to prevent system failures through a server gateway. This approach can improve machine efficiency by continuously monitoring it to avoid breakdowns and also determine preventive maintenance [16].

Smart meters have been extensively used in industry to supervise induction motors, providing easy access to evaluation of both mechanical and electrical factors. Long Range (LoRa) is the perfect wireless protocol for industries because of its secure communications, low energy consumption, and long range both outdoors and indoors. The study built a model for an affordable IM efficiency monitoring system based on LoRa [17]. The Arduino digital platform serves as the foundation for the system, which transmits the collected data over the LoRa and also cloud access gateway.

While monitoring the status of the traction motor drive in electric vehicles, an IoT system is used to measure the temperature, current, and vibration of the motor. An open-source software platform and commercially available components are used in the design and development of the IoT system to provide quick, dependable data collecting, minimal power consumption, and real-time reporting to a cloud server. According to the experimental findings, the IoT system can record crucial motor characteristics, send them to cloud servers, and instantly alert operators to anomalous motor behavior [18]. A sensor node is perfect for mobile applications since it consumes very little battery power thanks to cutting-edge power reduction techniques.

Finally, an artificial hummingbird optimization technique is established to detect unidentified parameters of Li-ion batteries in EVs. The technique mimics the unusual flying ability and sophisticated foraging strategies of wild hummingbirds by using axial, diagonal, and omnidirectional flights [18]. A visiting table is designed to replicate hummingbirds' memory function for food sources, and directed, territorial, and migrant foraging tactics are used. To evaluate the objective function and also standard deviation error in the dynamic prototype of Li-ion batteries, experiments are conducted on a 40 Ah Li-ion battery and the ARTEMIS drive cycle pattern [18].

The papers reviewed in this literature review highlight the potential of different techniques to enhance the performance of EVs and the efficiency of industrial motors. These techniques include optimization of design parameters, monitoring and control using the IoT, low-cost monitoring systems based on LoRa, and artificial hummingbird optimization techniques. These findings can contribute to the development of more efficient and sustainable technologies in research work.

Experimentation

Proposed methodology

The proposed system aims to enhance the monitoring process of a motor by integrating it with a set of sensors designed for measuring temperature, vibration, speed, current, voltage, and GMR flux, separately. These sensors provide continuous readings and graphs that can be conveniently accessed through IoT devices such as smartphones or computers. By utilizing these sensors, we can identify any potential faults in the motor, which can be influenced by various factors such as the environment, surroundings, power source, load, and other related aspects. The fault detection process is initiated when the data obtained from the sensors surpasses the threshold limit of the motor, which is indicated by an alarm buzzer. This method enables us to detect faults more precisely and rectify them promptly, which can ultimately extend the lifespan of the motor and reduce the risk of damage or failures. A block diagram is a visual representation of a system that utilizes blocks to denote the principal functions or parts connected by lines that indicate their relationships. Block diagrams have significant applications in different engineering domains, such as hardware design, software design, electronic design, and process flow diagrams. In this context, the block diagram depicted in figure 1 illustrates the fundamental concept of the research on modeling and performance analysis of an EV power drivetrain.

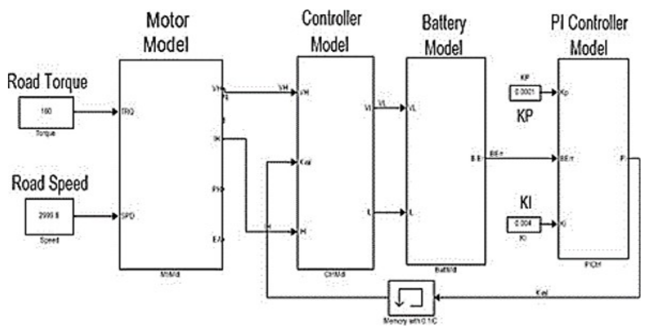

Figure 1: System block diagram.

The simulation model presented in the diagram simulates a basic electric motor-drive system in an EV, enabling the investigation of power flow during both motoring and regeneration. The simulation employs a DC permanent magnet motor, an ideal motor controller with a proportional-integral controller, and an EV battery. The model assesses the electric drive's energy flow and efficiency for specific torque and speed load conditions, where some system parameters are modeled as ideal, while others are specified. The developed and validated Simulink model provides stability to determine the system's performance and energy flow over motoring and regeneration speed/torque conditions. To facilitate monitoring and control, the controller is integrated with an IoT coding that allows data storage in cloud servers and access to readings and graphs on smart mobile phones or computers, through an app or website, from any location in the world. The cloud-based system offers real-time data access, enabling users to retrieve readings and performance analysis reports as needed, from anywhere and at any time.

Components and specifications

The electric motor controllers are crucial components used to regulate and control the working of an electric motor. The controllers are typically used in combination with variable frequency drives or switchboards to manage the prime mover's operation. The brushless DC (BLDC) motor is increasingly gaining popularity in several sectors, including automotive (especially EVs), HVAC, white goods, and industrial applications. This motor design eliminates the mechanical commutator found in traditional motors and substitutes it with an electronic device that enhances the unit's reliability and durability. Motor controllers provide an automatic or manual means of initiating and stopping the motor, deciding the direction of rotation, adjusting the speed, and controlling other operational parameters. Moreover, they can offer protection to the artificial lift system through regulating the torque, limiting overloads and faults.

Current sensors are critical components that detect and convert current to a measurable output voltage, which is directly proportional to the current flowing through the measured path. There is a broad range of current sensors available, and each type of sensor is suitable for a particular current range and environmental condition. The most commonly used current sensor is the current sensing resistor, which can be considered as a current-to-voltage converter. By inserting a resistor into the current path, the current is linearly converted to voltage. When current flows through a conductor, it generates a magnetic field around the conductor that is proportional to the current flow. Current transformers exploit this magnetic field to measure the current flow. The sensor then outputs a specific voltage or current that a connected meter can read and translate into the amount of current flowing through the conductor. Current transformers play an important role in regulating the current flow in electrical systems. These transformers can either step up or step down the current or maintain it at the same level. Typically consisting of two coils, current transformers are often referred to as transformers that modify current. The coil that the current passes through is known as the primary winding, while the coil that induces voltage is called the secondary winding.

On the other hand, a voltage sensor is designed to monitor and evaluate the voltage level of an object. These sensors are capable of determining both AC and DC voltage levels. Voltage sensors have varying output types, including switches, analog voltage signals, current signals, or even audible signals. Some sensors may generate sine waveforms or pulse waveforms, while others can produce outputs such as AM, PWM, or FM. The accuracy of voltage measurements by these sensors often depends on the use of a voltage divider. Asynchronous or induction motors are AC electric motors that generate torque using electromagnetic induction from the magnetic field of the stator winding. An induction motor's rotor can generate torque without any electrical connections, unlike other electric motors. The winding type and the squirrel-cage type of rotors can both be utilized in an induction motor. Three-phase squirrel-cage induction motors are frequently used in industrial applications because they are dependable, affordable, and self-starting. Single-phase induction motors are utilized for lighter loads, such as fans in home appliances. Induction motors were typically employed in fixed-speed applications in the past, but they are now more frequently used in variable-speed applications when coupled with variable-frequency drives. This presents enormous prospects for energy savings, particularly in variable-torque centrifugal. An electrical motor that uses the electromagnetic induction theory is known as an induction motor. The electromotive force that is induced in a conductor when it is exposed to a rotating magnetic field is the basis for this theory. The stator and the rotor are the two main components of an induction motor. Whereas the rotor, the motor's revolving component, carries the field winding, the stator, the motor's stationary component, includes overlapping windings. When a three-phase supply is connected to the stator, the motor may produce a spinning magnetic field since the windings are evenly spaced apart by an angle of 120 degrees. This rotor's induced currents from the rotating magnetic field result in torque. When an electrical conductor is put in a rotating magnetic field, the electromagnetic induction principle, which underpins how induction motors work, induces an electromotive force across the conductor.

The stator and the rotor are the two major parts of an induction motor. The overlapping windings are carried by the stator, the motor's stationary component, while the primary or field winding is carried by the rotor. The stator generates a rotating magnetic field when three-phase power is delivered, which causes the rotor's EMF.

The end rings or external resistance either short-circuit or induce current in the rotor conductors depending on how the rotor conductors move in relation to the spinning magnetic field. The rotor rotates in the same direction as the spinning magnetic field as a result of the electromagnetic torque produced by the interaction of the fluxes in the stator and rotor. The motor is referred to as an asynchronous motor since the rotor speed is never greater than the synchronous speed. Slipping is a result of the discrepancy between rotor and synchronous speeds.

Results and Discussion

The Simulink model used in this research provides a comprehensive simulation of an EV power drivetrain. Various metrics such as battery voltage, motor voltage, and temperature are simulated as in figure 2, from which simulated outputs like SOC and SOH are derived as in figure 3. The use of a display allows for constant monitoring of these metrics, without the need to carry around a laptop. The DC motor in the drivetrain produces torque in the rotational direction when both speed and torque have positive values, which is typical for car operation as in figure 4. When the motor torque is directed in the opposite direction from the speed, however, the motor functions as a generator. When the speed and torque are equal in polarity, the motor operates in driving mode. When an outside mechanical source is pushing the motor, however, the speed is positive and the torque is negative, the motor runs in regenerative mode figure 5. This results in energy being transmitted back into the battery. The relationship between motor voltage, current, and electricity is reflected in the voltage and torque equations. In the battery power plot, positive values for current and voltage indicate that power is being delivered to the load as in figure 6, with the motor producing torque in the direction of rotation. When the motor current and voltage are incompatible, the motor acts as a generator, feeding current back into the battery. The motor draws additional battery current as the required torque increases as in figure 7. Overall, this simulation provides a valuable tool for analyzing and optimizing EV power drivetrains.

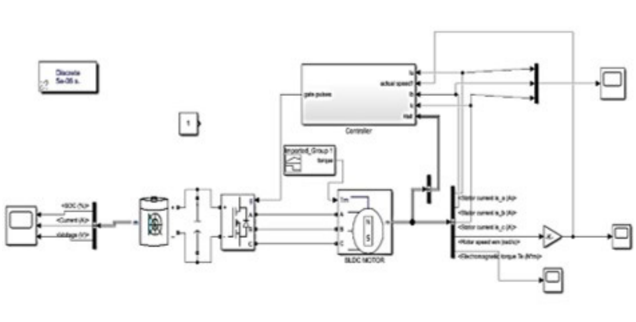

Figure 2: Simulation of EV power drive train.

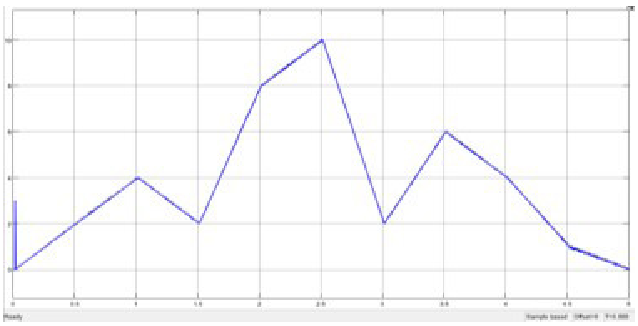

Figure 3: Desired torque output.

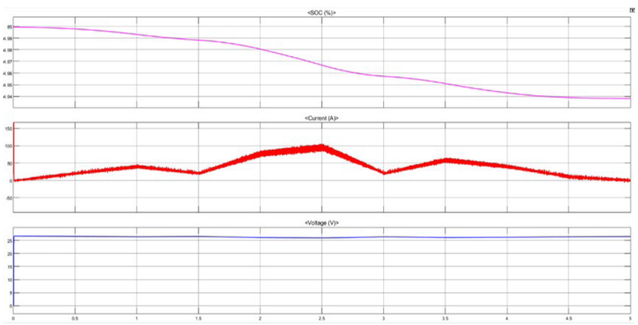

Figure 4: SOC current and voltage of the battery.

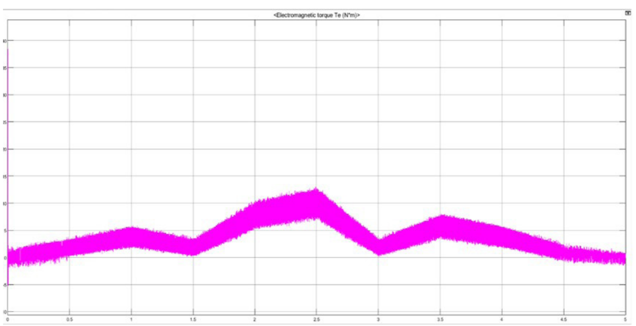

Figure 5: Output torque.

Conclusion

This innovative device offers real-time monitoring and measuring of electric motor parameters, which can improve industry growth and enhance motor efficiency. The measurement of many parameters is required for the motor system monitoring process, and the data gathered is saved and

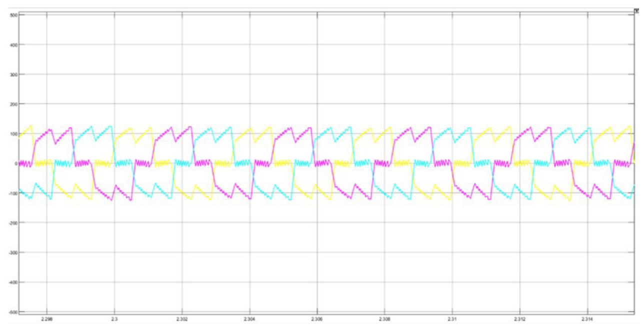

Figure 6: Current control signals.

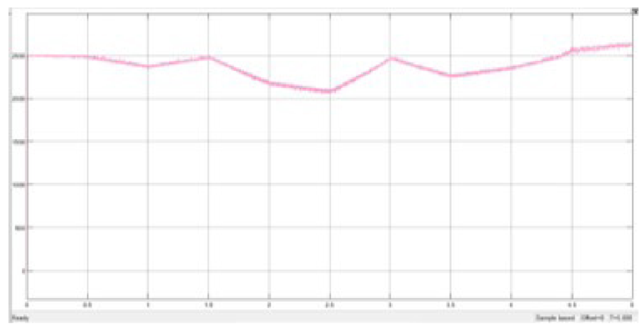

Figure 7: Rotor speed.

presented. EV development necessitates simulation, which should be incorporated into engineering education. Hardware-In-The-Loop testing is crucial in modern engineering development, particularly for complex embedded systems like hybrid and EV drive systems. The purpose of this research is to create a virtual model of an electric car to evaluate SOC, SOH, battery temperature, and other metrics. The research's primary goal is to use a cost-effective and time-efficient approach to modify EV performance to meet user needs. All of these results are displayed on a monitor. In our future research, we plan to completely integrate the IoT to remotely detect and monitor motor faults early. The motor's monitoring will be expanded to include measurements of vibrations per second, threshold temperature, speed, voltage, current consumption, and giant magnetoresistance flux induced. With the help of these measurements, we can identify and rectify motor issues based on the data collected.

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None.

Conflict of Interest

None.

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