

Performance Analysis of an Electric Motorcycle with IoT Based Monitoring

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ABSTRACT

The rapid shift toward electric vehicles (EVs) is reshaping the global transportation landscape, driven by the need for sustainable and energy-efficient alternatives to internal combustion engine (ICE) vehicles. Among various EV categories, electric motorcycles (E-bike) have emerged as a practical solution for urban mobility due to their compact size, low emissions and reduced operational costs. However, challenges such as performance reliability, battery efficiency, and system integration must be addressed to support their widespread adoption. This study presents the design and implementation of an Internet of Things (IoT)-based monitoring system for real-time performance evaluation of an E-bike. The system integrates multiple sensors to monitor key parameters, including battery voltage, current, temperature, wheel RPM, bike speed, and AC power consumption during charging. Real-time data is displayed on an onboard LCD and uploaded to the ThinkSpeak IoT platform for remote monitoring and future analysis. During charging, the battery voltage increased steadily with the AC charging current drawn by the battery is around 1.5 A. The charging power averaged around 218 W, demonstrating that the bike can be conveniently charged using a standard household power socket. From the data and the graph, it may be predicted that to charge the battery fully it will take around 8 to 10 hours. In discharging tests, motor current showed a linear correlation with speed, and power consumption increased accordingly, peaking at higher speeds. The battery range was estimated at 60 – 65 km per full charge. Battery and component temperatures rose gradually and linearly during operation, with no abrupt spikes, suggesting effective thermal management. The results confirm that IoT integration enhances the reliability, safety, and user awareness of E-bike performance. The developed system provides a valuable framework for future smart mobility solutions and lays the groundwork for more advanced electric vehicle management systems aimed at improving efficiency and user experience.

Keywords: Electric Motorcycle (E-bike), Internet of Things (IoT), Real-Time Monitoring and Battery Performance

1. INTRODUCTION

Electric motorcycles are two-wheeled vehicles powered by electric motors and rechargeable batteries, representing a shift away from internal combustion engines (ICE) traditionally used in motorcycles. With advancements in battery technology, motor efficiency, and charging infrastructure, electric motorcycles have gained significant traction in recent years, offering a cleaner, quieter, and more energy-efficient alternative to gasoline-powered bikes [1]. Unlike conventional motorcycles, electric motorcycles deliver instant torque, providing superior acceleration and a smoother ride. They are nearly maintenance-free due to fewer moving parts, lack of oil changes, and absence of complex exhaust systems. Modern electric motorcycles also incorporate

advanced technologies such as regenerative braking, smart connectivity, and customizable ride modes, enhancing the rider's experience [2].

Electric motorcycles play a crucial role in addressing some of the most pressing challenges associated with transportation today, including air pollution, greenhouse gas emissions, and noise pollution [3]. Their importance can be summarized in several key points:

Reduction of Greenhouse Gas Emissions

Transportation accounts for a significant share of global carbon dioxide (CO₂) emissions, with motorcycles contributing to this problem. Electric motorcycles produce zero tailpipe emissions, significantly reducing their carbon footprint compared to gasoline-powered vehicles.

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When powered by renewable energy sources, their environmental impact is further minimized, supporting global efforts to combat climate change.

Improved Urban Air Quality

In densely populated urban areas, vehicle emissions are a major contributor to air pollution, leading to respiratory and cardiovascular diseases. Electric motorcycles eliminate exhaust emissions, making them an ideal solution for reducing air pollution and improving public health, especially in cities.

Energy Efficiency

Electric motors are inherently more efficient than internal combustion engines. While ICE motorcycles convert only about 20 – 30% of the energy from fuel into motion, electric motorcycles can achieve efficiencies of 85 – 90%. This high efficiency means more energy is used for actual movement, reducing overall energy consumption.

Noise Pollution Reduction

Electric motorcycles operate much more quietly than their gas-powered counterparts, which can significantly reduce noise pollution in urban environments. This is especially important in residential and high-traffic areas, where excessive noise negatively impacts quality of life.

Support for Renewable Energy Integration

Electric motorcycles can be charged using electricity generated from renewable energy sources such as solar, wind, and hydroelectric power. This promotes the integration of clean energy into the transportation sector and reduces reliance on fossil fuels.

Economic and Social Benefits

- **Lower Operating Costs:** Electric motorcycles have lower operating costs due to reduced fuel expenses and maintenance requirements, making them an attractive option for cost-conscious consumers.
- **Energy Security:** By reducing dependence on imported fossil fuels, widespread adoption of electric motorcycles contributes to energy security at a national level.
- **Job Creation:** The electric vehicle industry, including manufacturing, battery development, and charging infrastructure, is a growing sector that creates new opportunities for employment and economic growth.

Addressing Global Sustainability Goals

Electric motorcycles align with global initiatives like the Paris Agreement, which aims to limit global warming, and the United Nations Sustainable Development Goals (SDGs), particularly Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action).

The demand for electric motorbikes is increasing in Bangladesh for being an eco-friendly, cost-effective mode of transport and government policy and support [4]. In 2020, the Bangladesh Road Transport Authority issued a policy for registering electric vehicles. The use of electric motorbikes has increased since then, with the biggest spike seen in 2022 [5]. The adoption of electric two-wheelers has ramped up as they are more environmentally friendly and cost-effective than those powered by fossil fuel. Besides, advancements in the required components, such as quickly rechargeable batteries and lightweight motors, are also driving demand.

One such contribution to this sustainable transportation movement is the electric bike named “Bondhu” developed by Akij Motors. As a locally manufactured electric bike, Bondhu aims to provide an eco-friendly and cost-effective alternative to traditional fuel-based motorcycles. While the adoption of electric bikes is increasing, the ability to continuously monitor and analyze the performance of these vehicles in real-time remains limited. This gap opens up an opportunity for research and development in intelligent monitoring systems that can ensure better efficiency, reliability, and user experience.

Since the industry is rapidly growing, there is a need of performance testing of these vehicles. On the other hand, if during testing and running, the required values like current, voltage, speed is logged and monitored, it will be a good opportunity for the researcher and motorcycle owner to observe and analyze his vehicle. Design of electric motorcycle has been done in [6]. In their paper, the authors have tested the electric motorcycle and given some test data but these are not monitored online. Intelligent monitoring of motorcycle was implemented in [7] where IoT based safety monitoring like speed monitoring and whether the driver has worn the helmet or not has been monitored. The authors of [8] proposed a preliminary road test procedure used to measure and collect the performance characteristics data of electric motorcycles. They have not used any IoT devices to monitor and record the test data.

This research project focuses on the Internet of Things (IoT)-based performance analysis and controller

evaluation of the Bondhu electric bike. The core objective of this work is to implement a smart system that collects, analyzes, and transmits real-time data related to the bike's electrical and mechanical parameters. To achieve this, various sensors have been integrated into the bike's system. DC current and voltage sensors are used to monitor the battery's behavior during charging and discharging cycles. These readings are crucial for understanding the efficiency of energy storage and usage. To evaluate the power input to the charger, AC current and voltage sensors are used to monitor the alternating current drawn from the grid. This helps assess the power consumption during charging and overall energy conversion efficiency. A temperature sensor is installed to measure the temperature of the battery. Since battery temperature significantly affects the performance and lifespan of electric vehicles, this data ensures safe and optimal operation. An infrared (IR) based speed sensor is also implemented to measure the rotational speed (RPM) of the wheels. This data is then used to calculate the real-time speed of the bike, which is vital for analyzing ride dynamics and energy usage during motion. All the collected data is displayed on an LCD screen mounted on the bike for local monitoring. In addition, the data is uploaded to the ThinkSpeak IoT platform, allowing remote access to the bike's condition from anywhere via the internet. This feature enables users or researchers to monitor battery health, charging status, temperature, and speed in real-time, providing valuable insights into the overall performance of the bike.

The primary aim of this research is to create a low-cost, real-time monitoring and data analysis system for electric bikes. This system not only provides a deeper understanding of the performance and control behavior of the Bondhu electric bike but also sets a foundation for future development of intelligent electric vehicles in Bangladesh. With further advancements, such systems can be expanded to include predictive maintenance, performance optimization, and integration with smart transportation infrastructure.

The aims of this project are:

- To design and implement a real-time performance monitoring system for an electric bike.
- To analyze different data of battery, motor and controller to check the performance of these devices.
- To use IoT devices for remote monitoring of different parameters of the battery, motor and controller using mobile phone or PC.

2. IMPLEMENTATION OF THE PROJECT

The implementation of this project involved the integration of multiple hardware components and sensors with a microcontroller-based system to monitor the performance of the Bondhu electric bike. DC current and voltage sensors were used to track the battery's charging and discharging status, while AC sensors monitored the power input during the charging process. A temperature sensor was installed to observe the thermal condition of the battery, and an IR-based speed sensor was used to measure the wheel's RPM and calculate the bike's speed. All collected data was displayed on an LCD screen for local monitoring and simultaneously uploaded to the ThinkSpeak IoT platform for remote access and analysis. This implementation enabled a comprehensive and real-time evaluation of the electric bike's performance and controller behavior.

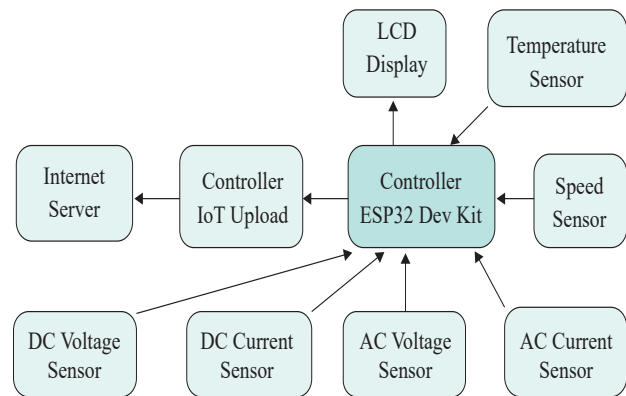


Fig. 1: Block diagram of the system

This block diagram in Fig. 1 illustrates a system centered around an ESP32 Dev Kit, acting as a controller to monitor various electrical and electric bike parameters. It interfaces with DC and AC voltage and current sensors, a temperature sensor, and a speed sensor to gather data. This information is then displayed on an LCD and uploaded to an internet server via a controller for IoT upload, suggesting a remote monitoring or control application.

In order to implement the project, several components have been used (given in Table I)

Table I: Component list of the project

Sl. No.	Component's Name	Required Quantity
1.	ESP32 Dev Kit	2 Nos.
2.	AC Current Sensor (ZMC103C)	1 No.
3.	AC Voltage Sensor (ZMPT101B)	1 No.
4.	DC Current Sensor (ACS712-30A)	1 No.

Sl. No.	Component's Name	Required Quantity
5.	DC Voltage Sensor Module	1 No.
6.	Temperature Sensor (DS18B20)	1 No.
7.	IR Sensor	1 No.
8.	Buck Converter	1 No.
9.	Mobile Phone	1 Unit
10.	Akij Bondhu Electric Bike	1 Unit
11.	Multimeter	1 Unit
12.	LCD Display with I2C Module	1 No.

The system collects real-time data on battery status, charger input, battery temperature, and bike speed. This data is displayed on the LCD and simultaneously uploaded to ThingSpeak for remote performance monitoring. The diagram provides a clear view of the signal flow and system functionality, ensuring easy implementation and troubleshooting. Figure 2(a) and (b) show the implemented circuit with the sensors. The implemented circuit is mounted on the rare side of the bike in a box.



(a)



(b)

Fig. 2: Assembled circuit with sensors in the electric bike

2.1 Working Principle

The IoT-based electric bike performance monitoring system is designed to continuously collect and analyze key parameters related to the bike's battery and overall ride performance. The system utilizes two ESP32 Dev Kits for optimized functionality. One ESP32 is dedicated for sensor data collection and processing, while the second ESP32 handles Wi-Fi-based IoT communication, uploading the data to ThingSpeak server for remote monitoring.

The system integrates several sensors to monitor different parameters of the bike's performance. The DC voltage and current sensors are connected to the series connected five 12V batteries on the bike, allowing real-time tracking of battery health. Battery voltage and current flow are continuously monitored to assess the charging and discharging processes. To monitor the energy input, AC voltage and current sensors are installed on the charger input. The AC voltage typically ranges from 220V to 250V, ensuring the proper charging voltage is being supplied to the bike. These sensors provide real-time feedback on how much power is being drawn from the grid during the charging process. A DS18B20 temperature sensor is placed near the battery to measure its temperature. This is crucial for maintaining optimal operating conditions and preventing overheating, which could cause battery damage or reduced lifespan. The temperature data allows the system to detect abnormal conditions that could affect the bike's overall performance and safety. An IR-based speed sensor is used to measure the wheel's RPM, which is then converted into speed in kilometers per hour. This sensor provides real-time feedback on the bike's speed, offering valuable data for both the rider and for performance analysis.

The main ESP32 unit collects all the sensor data, processes it, and sends it to the second ESP32, which is solely responsible for uploading this information to ThingSpeak. Once uploaded, the data can be accessed remotely on ThingSpeak, where it is visualized in real-time. The monitored parameters include battery voltage (for each of the five batteries), battery current, AC voltage (220-250V), AC current, temperature, speed (in km/h), and battery status in percentage. The system's ability to display battery status in percentage is especially useful for keeping track of the bike's charge level and ensuring the rider is aware of remaining battery life. This setup enables users to monitor the performance of their electric bike in real-time, providing insights into battery health, charging efficiency, ride speed, and temperature, while also enabling proactive maintenance through remote monitoring.

2.2 Calibrations

Calibration in this system involves adjusting the sensors to ensure accurate data readings. Each sensor, such as the voltage, current, and temperature sensors, is calibrated to standard values using known reference measurements. This ensures that the data collected from the bike, such as battery voltage, current, and temperature, are accurate and reliable. Regular calibration helps maintain the system's precision and ensures that performance monitoring remains correct over time. To calculate the percentage error, we have used the formula:

$$\%Error = \left(\frac{Sensor\ Value - Actual\ Value}{Actual\ Value} \right) \times 100\%$$

The maximum errors for DC voltage, AC voltage, DC current, AC current, temperature, and speed were found to be 0.87%, 0.91%, 2.00%, 2.38%, 1.85%, and 7.00%, respectively.

3. RESULTS AND DISCUSSION

A 20×4-character LCD display has been used here with I2C interface to display the different measured parameters of the e-bike. At the same time IoT technology has been used to upload the data to the ThingSpeak server. This allows for real-time storage and visualization of the electric bike's performance data, including parameters such as battery voltage, current, speed, temperature, and battery storage status.

To present the results, we have divided the analysis into two main parts: charging conditions and discharging conditions. Under charging conditions, we present the trends such as AC charging current, power consumption of the battery, battery voltage and % of battery storage. In the discharging condition, we analyzed the trends like battery supplied current and power consumption of the motor for different speed, % of battery storage with distance, battery voltage related to % of battery storage, temperature variation with distance etc. These trends provide valuable insights into the electric bike's performance under both charging and discharging scenarios. Fig. 3(a) shows the data on mobile phone when the AC voltage was applied for charging battery. On the other hand, Fig. 3(b) shows the different parameters of the e-bike when the bike is running on the road.

During Charging Data

Battery Voltage	: 63.13
Battery Current	: 0.00
Speed(Kmph)	: 0.00
Battery Temperature	: 29.69
Charging AC Voltage	: 233.63
Charging AC Current	: 1.49
Battery Status	: 54.00

(a)

Running Condition Data

Battery Voltage	: 61.52
Battery Current	: 6.48
Speed(Kmph)	: 32.00
Battery Temperature	: 30.37
Charging AC Voltage	: 0.00
Charging AC Current	: 0.00
Battery Status	: 48.00

(b)

Fig. 3: Data showing in the phone while (a) charging and (b) running condition

3.1 Different Parameters of the Electric Bike During Charging

This section discusses and demonstrates the behavior of the electric bike under charging conditions. It shows how various parameters, such as AC charging current, power consumption of the battery, battery voltage and % of battery storage over time providing insight into the performance of the bike during the charging process.

The AC charging current drawn by the battery during charging is shown in Fig. 4. The graph shows that the AC current drawn by the battery is around 1.5 A. At that time the battery voltage gradually increases from 56 V to 64 volts and the maximum value is controlled by the charge controller. The average power required for charging is around 218 W which indicates that the e-bike can be charged with a simple household power socket.

The graph in Fig. 5, illustrates the charging behavior of an electric bike battery over a period of 120 minutes. It shows a steady increase in battery charge percentage, starting from 40% and rising to 60%. From the data and the graph, it may be predicted that to charge the battery fully it will take around 8 to 10 hours. This gradual rise indicates a consistent charging process, likely under a constant voltage or current mode.

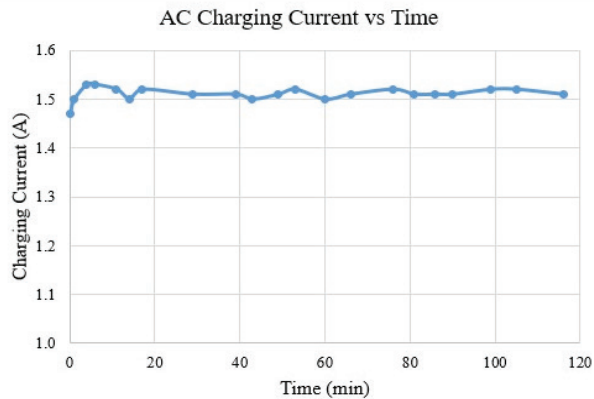


Fig. 4: AC current drawn by the battery vs time during charging

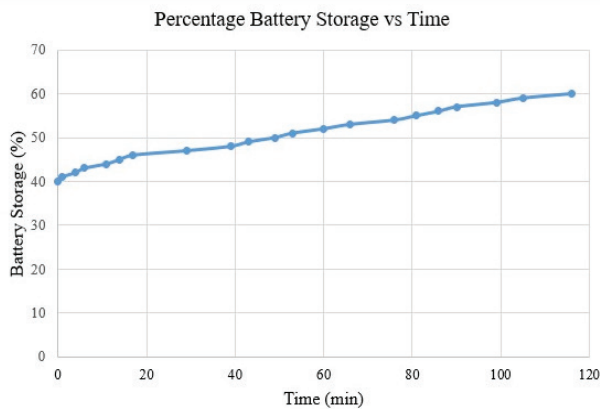


Fig. 5: Percentage of battery storage vs time

3.2 Different Parameters During Discharging/Running Condition

The relationship between the battery supplied current i.e. current drawn by the motor and the speed of the electric bike is shown in Fig. 6. The data shows a linear increase in motor current as the bike's speed increases, indicating a proportional relationship between speed and current demand. As the bike accelerates, the motor requires more current to maintain higher speeds, resulting in a steadily rising curve. At that time the power demand by the motor varies from 70 to 419 W.

The trend of battery percentage decreasing over distance travelled during the operation of the electric bike is shown in Fig. 7. As the bike runs, it consumes electrical

energy to power the motor and other electronic systems, leading to a gradual decline in battery charge. This reduction of battery percentage also reduces the battery terminal voltage and it varies from 60.5 to 58.2 V. It is clear from the graph that after running around 12 km the battery % decreases around 8% so we can predict that for a fully charged bike around 60 to 65 km can be run before it needs charging. We have also observed the temperature rise of the battery and the surroundings at that time which was from 31.10 to 31.75 °C as shown in Fig. 8.

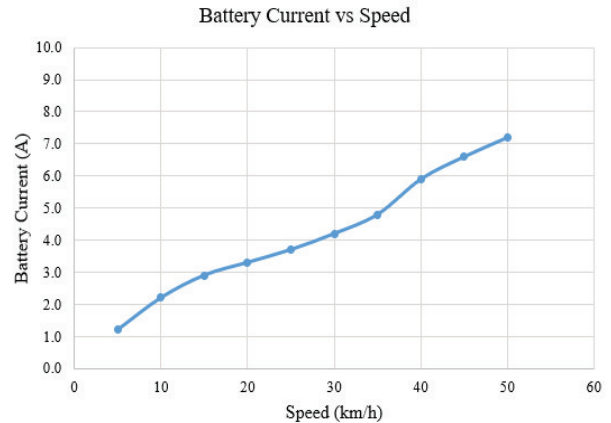


Fig. 6: Battery current vs speed

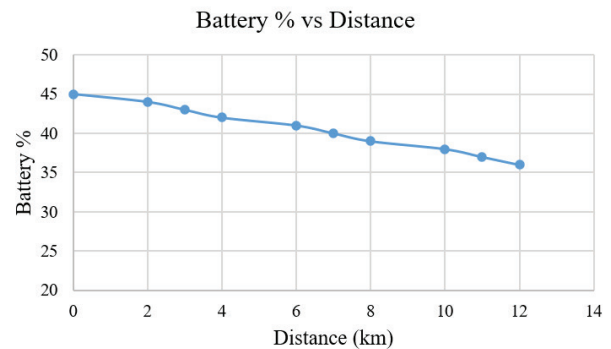


Fig. 7: Battery % vs distance

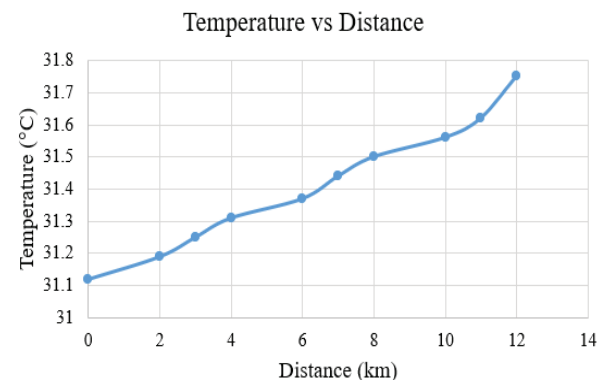


Fig. 8: Battery temperature rise trend

4. CONCLUSION

The global transportation sector is undergoing a significant transformation with the rapid adoption of EVs as a sustainable alternative to fossil fuel-based vehicles. Among EVs, electric motorcycles (e-motorcycles) have gained considerable attention due to their compact size, energy efficiency, and lower operational costs compared to cars. However, the widespread adoption of e-motorcycles faces challenges related to performance, reliability, and battery lifespan. Unlike conventional motorcycles, which rely on well-understood internal combustion engines, e-motorcycles depend on the seamless integration of three critical components like electric motor, battery pack and motor controller. A minor inefficiency in any of these components can lead to reduced range, overheating, or even catastrophic failure, highlighting the need for rigorous performance testing and real-time monitoring.

In the present work, through the integration of various sensors, the system was able to continuously monitor critical parameters such as battery voltage, battery current, battery temperature, wheel RPM, bike speed, and AC power consumption during charging. By utilizing DC and AC voltage and current sensors, the charging and discharging behaviors of the bike's battery were effectively analyzed. An IR-based speed sensor accurately measured the wheel's RPM, enabling reliable calculation of the bike's speed. The system's continuous tracking of battery temperature ensured operational safety by identifying any unusual heating patterns. The real-time data was displayed on an onboard LCD screen, providing immediate feedback to the user, and was simultaneously uploaded to the ThinkSpeak IoT platform for remote monitoring and future analysis. This dual approach of local and cloud-based data presentation enhanced the accessibility and usefulness of the monitoring system.

The analysis of the electric bike's performance under both charging and discharging conditions provides valuable insights into its operational efficiency, energy consumption, and battery behavior. During charging, the battery voltage increased steadily with the AC charging current drawn by the battery is around 1.5 A. The charging power averaged around 218 W, demonstrating that the bike can be conveniently charged using a standard household power socket. The battery charge percentage showed a steady increase in battery charge percentage, starting from 40 % and rising to 60 %. From the data and the graph, it may be predicted that to charge the battery fully it will take around 8 to 10 hours. Under discharging (running) conditions, the motor current exhibited a linear relationship with speed, reflecting higher current

demand as the bike accelerated. Power consumption also increased with speed, peaking at higher velocities due to greater energy requirements. The battery percentage decreased non-linearly with distance, with an estimated range of 60 – 65 km on a full charge. Temperature monitoring revealed a gradual and linear rise in battery and component temperatures during operation, suggesting effective thermal management without abrupt spikes.

Overall, the project demonstrated the effectiveness of combining IoT technology with electric vehicle systems for smart monitoring. The data collected and analyzed through this project will not only support further improvement of the "Bondhu" electric bike but will also contribute to future developments in smart electric mobility solutions. This work lays the foundation for more advanced and intelligent electric vehicle management systems aimed at enhancing safety, efficiency, and user experience.

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