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DEVELOPMENT OF IOT-BASED MOTORCYCLE ELECTRICAL LEARNING MEDIA

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Abstract: *The development of Industry 4.0 toward Society 5.0 requires innovation in vocational learning media based on Internet of Things (IoT) for motorcycle electrical systems. This study aims to develop a learning media for real-time monitoring and fault diagnosis. The method used is Design Based Research (DBR) consisting of analysis, design, development, and testing stages. The system integrates an ADC voltage sensor (12.6 V normal; ADC ≈ 859 and 12.1 V weak; ADC ≈ 820), pull-up resistor switch detection (logic 0 = 0 V normal; logic 1 = 5 V fault), ACS712 current sensor (1.5 A lamp ON; ADC ≈ 568 and 0 A fuse fault; ADC ≈ 511), and INA219 charging sensor (14.0 V normal charging; ADCbus ≈ 3500 and 12.4 V not charging; ADCbus ≈ 3100). The results show that all sensors operate stably and accurately in detecting both normal and fault conditions. Integration into a web-based dashboard enables real-time monitoring via computers and smartphones. Therefore, the developed learning media effectively improves students' understanding, visualization, and analytical skills in IoT-based motorcycle electrical systems.*

Keywords: *ACS712; ADC; Design Based Research; INA219; IoT; Motorcycle Electrical System; Learning Media*

Abstrak: Perkembangan Revolusi Industri 4.0 menuju Society 5.0 menuntut inovasi media pembelajaran vokasi berbasis Internet of Things (IoT) pada sistem kelistrikan sepeda motor. Penelitian ini bertujuan mengembangkan media pembelajaran untuk monitoring dan diagnosis kerusakan kelistrikan secara real-time. Metode yang digunakan adalah Design Based Research (DBR) melalui tahap analisis, perancangan, pengembangan, dan pengujian. Sistem menggunakan sensor ADC (12,6 V normal; ADC ≈ 859 dan 12,1 V lemah; ADC ≈ 820), pull-up resistor (logika 0 = 0 V normal; logika 1 = 5 V kerusakan), ACS712 (1,5 A lampu ON; ADC ≈ 568 dan 0 A saat sekring putus; ADC ≈ 511), serta INA219 (14,0 V charging normal; ADCbus ≈ 3500 dan 12,4 V tidak mengisi; ADCbus ≈ 3100). Hasil pengujian menunjukkan seluruh sensor bekerja stabil, akurat, dan sesuai fungsi dalam mendeteksi kondisi normal maupun fault pada sistem kelistrikan. Integrasi data sensor ke dashboard web memungkinkan pemantauan real-time melalui perangkat komputer dan smartphone. Dengan demikian, media pembelajaran yang dikembangkan efektif meningkatkan pemahaman, visualisasi, dan kemampuan analisis peserta didik pada sistem kelistrikan sepeda motor berbasis IoT..

Kata kunci: ACS712; ADC; Design Based Research; INA219; IoT; Kelistrikan Sepeda Motor; Media Pembelajaran

INTRODUCTION

The development from Industry 4.0 to Society 5.0 demands vocational education, particularly in the Motorcycle Engineering and Business program at vocational high schools (SMK), to integrate digital technology into the learning process. However, learning media used today is still largely dominated by conventional methods such as textbooks, printed modules, and lectures, which are less capable of supporting competency mastery aligned with the advancement of modern automotive technology, such as electronic fuel injection systems, digital sensors, Electronic Control Units (ECU), and electric vehicles. This condition causes a gap between graduate competencies and the increasingly digital- and automation-based needs of the industry [2]. Therefore, it is necessary to develop more innovative, interactive, and technology-based learning media so that students can improve their technical competencies, digital literacy, critical thinking skills, and problem-solving abilities, which are key requirements in the era of the Fourth Industrial Revolution toward Society 5.0.

The continued use of conventional learning media that does not keep up with technological developments can lead to low understanding of technical concepts, suboptimal practical skills, decreased student learning motivation, and poor learning outcomes that do not meet the needs of modern industry. This condition creates a competency gap among students, particularly in mastering the technologies and skills required in the era of the Fourth Industrial Revolution toward Society 5.0.

Various studies show that learning media have a positive effect on students' learning outcomes, learning interest, and learning motivation. The use of interactive multimedia-based learning media has been proven to improve student learning outcomes. In addition, learning media also has a significant influence on students' learning interest. Other studies show that the appropriate use of learning media can significantly increase students' learning motivation.

Therefore, to address the learning challenges in the era of the Fourth Industrial Revolution toward Society 5.0, the researcher seeks to develop a motorcycle electrical system learning media that was previously conventional into a technology-based digital learning media. This development integrates Artificial Intelligence (AI), the Internet of Things (IoT), and web-based monitoring technology so that students do not only study the concepts of motorcycle electrical systems theoretically, but can also observe, analyze, and diagnose the system in real time through a web-based platform. The use of this technology is expected to enhance learning interactivity, simplify the visualization of electrical system processes, increase students' interest and learning outcomes, and produce graduates who are more adaptive to the development of modern automotive technology and industrial needs.

The developed motorcycle electrical system learning media integrates Internet of Things (IoT) technology so that electrical conditions and faults can be monitored in real time through an Android device connected to the tool's IP address. This design is installed on conventional learning media and is capable of detecting various faults, such as a depleted battery, broken switch, blown fuse, non-functioning lights, and charging system failures (regulator/rectifier). Fault information is automatically displayed on an Android device, making it easier for students to monitor and diagnose motorcycle electrical system failures using digital technology in accordance with the demands of the Fourth Industrial Revolution toward Society 5.0.

METODE

The method used in this study is Design-Based Research (DBR), which is a method focused on the development and refinement of learning media in stages based on real conditions in the field [12]. In the initial stage (analysis), an identification of problems related to motorcycle electrical system failures in vocational high schools (SMK) was conducted, including a depleted battery, broken switch, blown fuse, non-functioning lights, and charging system failure (regulator/rectifier). These five faults were selected because they occur most frequently and are relevant to the basic competencies of learning, thus serving as the foundation for developing technology-based learning media.

After identifying the faults, an analysis was conducted to determine the sensors capable of detecting each type of damage. To address these conditions: (1) a depleted battery is detected using a voltage sensor, (2) a broken switch is detected using a digital pin with a pull-up configuration, (3) fuse and non-functioning light conditions are monitored using the ACS712 current sensor, and (4) regulator/charging system failure is detected using the INA219 sensor, therefore requiring appropriate calculations for data conversion and system analysis.

Voltage Sensor [14]

$$V_{out} = \frac{ADC}{ADC_{\max}} xV_{ref} \quad (1)$$

$$jika, divider$$

$$V_{in} = V_{out} x \frac{R_1 + R_2}{R_2} \quad (2)$$

Pull-up down resistor [15]

$$I = \frac{V_{cc}}{R} \quad (3)$$

ACS 712 Sensor [16]

$$V_{out} = \frac{ADC}{ADC_{\max}} xV_{reff} \quad (4)$$

convert to current value

$$I = \frac{V_{out} - V_{offect}}{Sensitivitias} \quad (5)$$

INA 219 Sensor [17]

$$V_{buss} = ADC_{buss} xLSB_{voltage}$$

After the sensors were identified and the ADC values were converted into physical units according to their characteristics, the sensors were integrated into the electrical system of the modified learning media. The sensors were placed at measurement points to detect the condition and faults of the motorcycle electrical system in real time.

The measurement data is sent to the microcontroller and forwarded to the server for processing. Subsequently, a web-based monitoring application is developed that displays sensor data through a dashboard accessible via computer and smartphone. This enables users to monitor electrical conditions, identify faults, and analyze data in real time based on the Internet of Things (IoT).

RESULT AND DISCUSSION

After sensors were installed at each fault point as shown in the figure below.

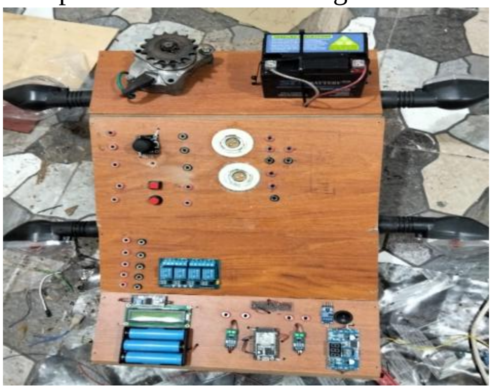

Figure 1 Display of the Motorcycle Electrical System Learning Media equipped with an AI and IoT-based monitoring system.

After the installation of each sensor on the conventional motorcycle electrical learning media, testing was conducted, including:

Test Accy with voltage sensor.

$$V_{out} = \frac{859}{1023} x5 = 0{,}839x5 = 4.19V$$

(6) divider with resistan 10kΩ and 5kΩ

$$V_{in} = 4{,}19x\frac{10+5}{5} = 4{,}19x3 = 12{,}57v$$

The system is able to read changes in battery voltage through stable and proportional ADC value conversion. The resulting ADC values show a linear relationship with input voltage changes according to Equations 1 and 2.

Testing of motorcycle light switch failure (open circuit) using a pull-up configuration with a 10 kΩ resistor.

$$I = \frac{5V}{10k\Omega} = 0{,}5mA$$

A current of 0.5 mA indicates normal operation with no short circuit, whereas if there is an open circuit (broken connection), no voltage is conducted and the current becomes 0.

Testing of motorcycle light and fuse faults using the ACS712 current sensor.

$$V_{out} = \frac{568}{1023} x5 \quad = 0{,}55x5 = 2{,}775V$$

convert to currnet

$$I = \frac{2{,}775 - 2{,}5}{0{,}185} = \frac{0{,}2775}{0{,}185} = 1{,}5A$$

This indicates that the light or fuse is in active or good condition, whereas if it is faulty, the Voffset value becomes 0, resulting in a current flow of 0.

Testing of the regulator to determine whether it is charging or not using the INA219 sensor.

$$V_{buss} = 3500x0{,}004 = 14V$$

If the ADC value is greater than 3500 and the Vbus is above 14 V, the regulator is in a charging condition. Conversely, if the ADC value is below 3500 or the Vbus is below 14 V, the regulator is not charging.

Table 2 Combined test results of the motorcycle electrical system integrated into the development of a conventional motorcycle electrical system training media.

No	Parameter Tested	Sensor	System Condition	Measured Value	Conversion Result	Status
1	Battery voltage	ADC (10kΩ–5kΩ voltage divider)	Normal battery	ADC ≈ 859	12.6 V	Normal
2	Battery voltage	ADC	Weak battery	ADC ≈ 820	12.1 V	Weak
3	Switch/light	Pull-up resistor	Connected (normal)	Logic 0	0 V	Normal
4	Switch/light	Pull-up resistor	Open circuit (fault)	Logic 1	5 V	Fault
5	Fuse/light	ACS712	Light ON	ADC ≈ 568	1.5 A	Normal
6	Fuse/light	ACS712	Fuse open	ADC ≈ 511	0 A	Fault
7	Charging regulator	INA219 (Vbus)	Charging	ADCbus ≈ 3500	14.0 V	Charging normal
8	Charging regulator	INA219 (Vbus)	Not charging	ADCbus ≈ 3100	12.4 V	Fault

The overall test results show that each sensor used in the system is able to function properly in detecting motorcycle electrical conditions. The ADC sensor with a voltage divider circuit successfully reads battery voltage conditions in a linear manner. The pull-up/pull-down sensor is able to distinguish the connected and disconnected states of switches or lamps through digital logic changes. The ACS712 sensor can detect current variations in the lamp load and fuse conditions, while the INA219 sensor is capable of identifying regulator operating conditions based on bus voltage (Vbus) values.

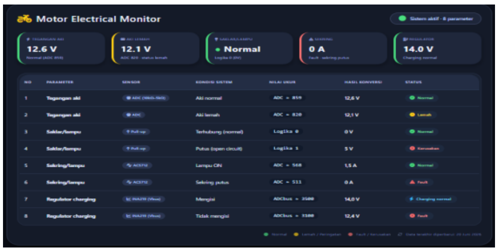

Figure 4 Display of the motorcycle electrical system condition as viewed on an Android device.

The image shows the dashboard of the Motor Electrical Monitor IoT-based system for real-time monitoring of motorcycle electrical conditions. The top section displays main parameters such as battery voltage, system status, current, and charging voltage from the regulator. The table section presents sensor readings (voltage, switch status, current, and charging condition) along with their status classification as normal, warning, or error. This system is used to digitally analyze motorcycle electrical fault conditions through web-based monitoring.

CONCLUSION

Based on the test results of the Motor Electrical Monitor system, the battery voltage was found to be 12.6 V (normal) with the main system condition detected as stable. Other voltage readings show 12.1 V at one measurement point, indicating a slightly weak condition, measured current of 0 A on a certain load (no current flow), and regulator charging voltage of 14.0 V indicating an active charging process. Overall, the system successfully classifies electrical conditions into normal, warning, and error categories in real time according to the sensor data obtained..

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