Volume 2, Issue 2

Innovation Series Quarterly

https://journal.academicapress.org/aps/index.php/isq

Research Article

Development of Smart KERS-Kit: An Interactive Pedagogical Tool for Hybrid Electric Vehicle (HEV) Education

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Keywords:
Smart KERS-Kit;
Energy Conversion;
TVET;
Interactive Learning;
Real-Time Data Visualization

Abstract: *This study was conducted to address the lack of practical exposure and the absence of real-time data visualization in Kinetic Energy Recovery System (KERS) learning for TVET students. This innovation-based research approach involves the development of Smart KERS-Kit through experimental methods and quantitative analysis. The system integrates mechanical movement, electrical energy conversion as well as microcontroller controls to display real-time data. The findings show a consistent linear relationship between the motor's rotational speed and voltage and power output, thus proving the efficiency of energy conversion. Overall, this kit is effective as an interactive teaching aid that enhances students' understanding of concepts, practical skills, and engagement.*

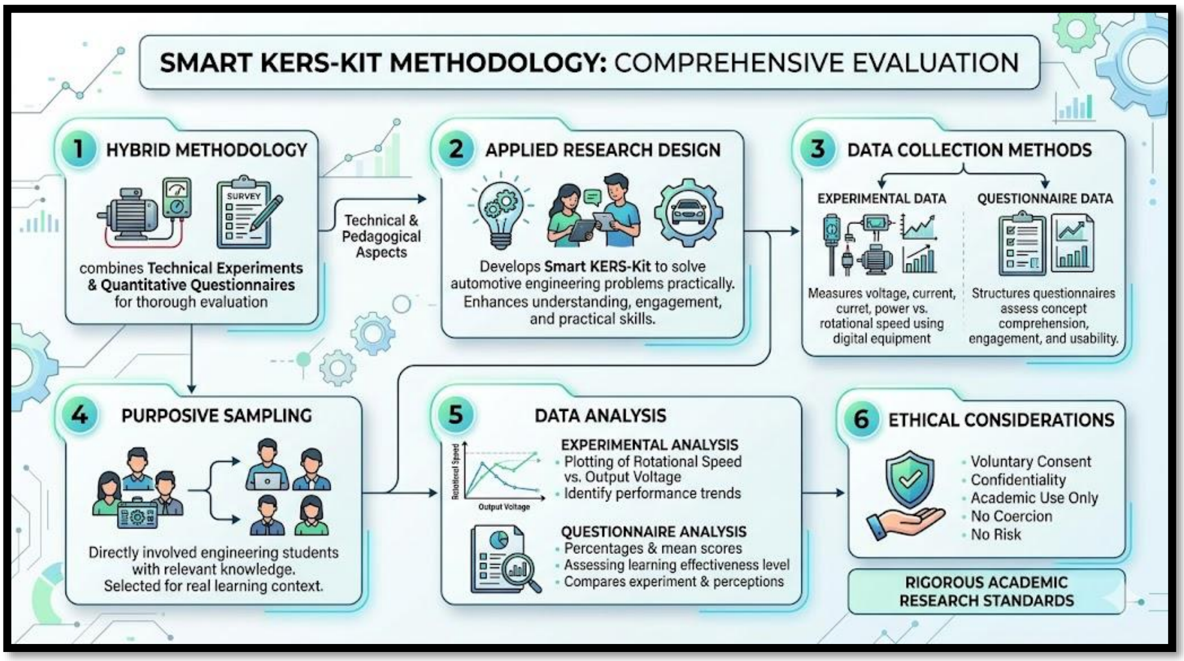
1. INTRODUCTION

The automotive sector is now rapidly moving towards hybrid vehicle (HEV) technology to support environmental sustainability, where the KERS system converts energy while braking into electricity for reuse, thus improving energy efficiency. However, in engineering and TVET education, this concept is still widely taught in theory, causing students to lack a good understanding of the actual application and affecting learning achievement. In addition, existing teaching aids also lack to integrate mechanical, electrical, and control system aspects and do not provide real-time data displays for clearer analysis (Gunawardana, Perera, & Silva, 2024). Therefore, this study was conducted to develop a Smart KERS-Kit prototype that combines mechanical systems, energy conversion and microcontrollers to enable real-time energy efficiency analysis based on the relationship between motor speed and electrical output such as voltage and power, while supporting the development of green education, TVET and industrial human capital through a hands-on learning approach (Lopez, Garcia, & Torres, 2025; Jamil, Ramli, & Hassan, 2024).

2. LITERATURE REVIEW

The automotive sector is currently evolving towards sustainable vehicles through the use of Hybrid Electric Vehicle (HEV) technology, where the Kinetic Energy Recovery System (KERS) works to convert mechanical energy during braking into electrical energy to be stored and reused, thus improving energy efficiency and reducing heat loss (Mazzola et al., 2024). However, this development needs to be supported by changes in engineering education and TVET as learning is still largely theory-focused, while practical exposure and actual experience are still limited which can affect students' understanding, memory and engagement . In line with the Industrial Revolution 4.0, the use of Arduino microcontrollers and smart sensors in teaching aids allows mechanical movements to be converted into digital data more efficiently, at low cost and easily analyzed, while increasing the accuracy of energy performance analysis as well as students' interest in technical skills (Brito et al., 2025; Lopez, Garcia, & Torres, 2025). However, most educational simulation models are still weak in terms of real-time data visualization and integration between mechanical systems and digital systems, making it difficult for students to understand the energy conversion process as well as the relationship between motor rotation speed and electricity production (Gunawardana, Perera, & Silva, 2024; Othman, Ismail, & Ahmad, 2024). Therefore, the development of Smart KERS-Kit is important as it combines mechanical rotation, energy conversion and real-time telemetry systems to support hands-on learning as well as live digital monitoring.

3. METHODOLOGY



4. FINDINGS

4.1 Technical Factors Affecting System Integration

The findings of this study are presented based on two main objectives, namely to identify the technical factors that influence the integration of the Smart KERS-Kit system and to analyze the efficiency of electrical energy conversion based on the relationship between the motor rotation speed and electrical output. For the first objective, the findings show that the effectiveness of system integration depends on the compatibility between key components such as DC motors, generators, sensors and microcontrollers. DC motors produce mechanical movements that are converted into electrical energy by generators, in line with thermodynamic principles. Sensors are responsible for accurately measuring rotational speed and voltage, while microcontrollers act as control centres to collect, process and display data in real-time to ensure stable system function.

Table 4.1: Technical Factors Affecting System Integration

Components	Function	Impact on the System
Motor DC	Generates mechanical movement	Determining kinetic energy inputs
Generator	Converting mechanical energy into electricity	Determining energy conversion efficiency
Sensors	Measuring RPM and voltage	Affects data accuracy
Microcontrollers	Controlling and processing data	Guarantee system stability and integration

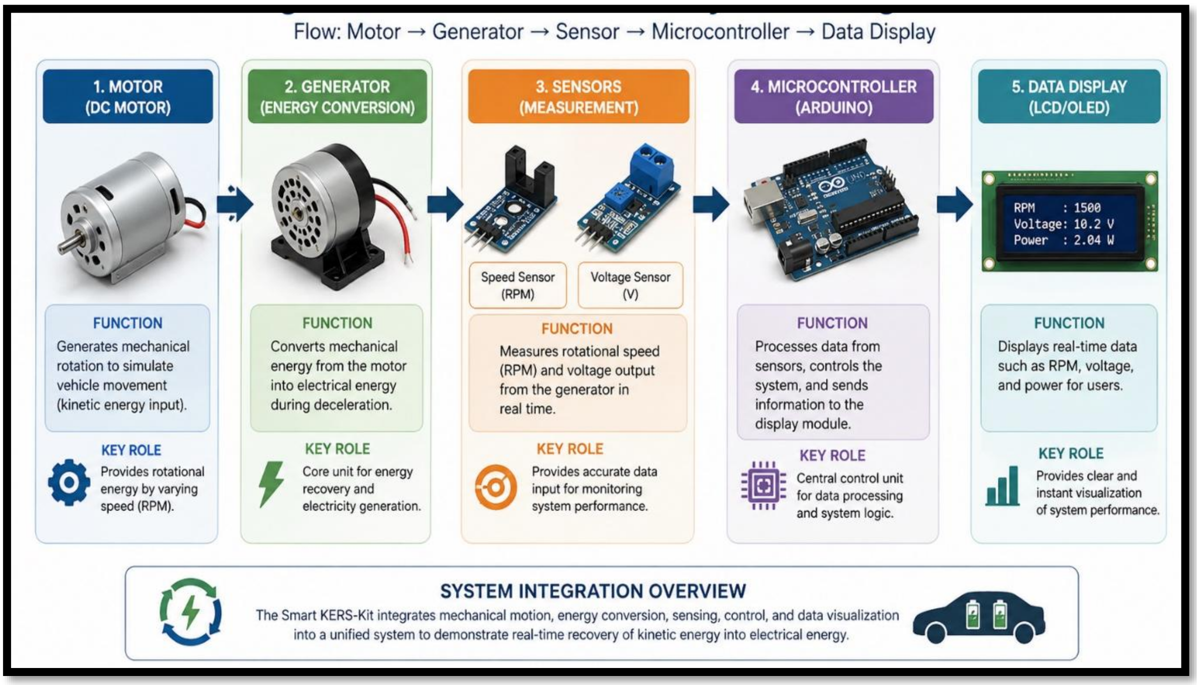


Figure 4.1: KERS-Kit Smart System Integration

These findings show that good integration between the components results in a stable and responsive system. On the other hand, an imbalance in any component can affect the overall performance of the system. Therefore, this technical factor is a critical element in the development of technology-based teaching aids.

4.2 Performance Analysis of Energy Conversion Efficiency

For the second objective, the performance analysis of the system shows a clear relationship between the speed of rotation of the motor and the electrical output produced. Experimental data show that an increase in rotation speed (RPM) results in a proportional increase in voltage and power, thus demonstrating good energy conversion efficiency.

Table 4.2: Relationship between rotational speed and electrical output

Speed (rpm)	Voltage (v)	Current (a)	Power (w)
500	3.2	0.10	0.32

1000	6.5	0.15	0.98
1500	10.2	0.20	2.04
2000	15.0	0.25	3.75
2500	21.5	0.30	6.45

Based on the table 4.2, it can be observed that the voltage increases linearly as the rotation speed increases. The same goes for the power value which shows a significant increase at high speeds. This proves that the Smart KERS-Kit system is capable of converting kinetic energy into electricity efficiently.

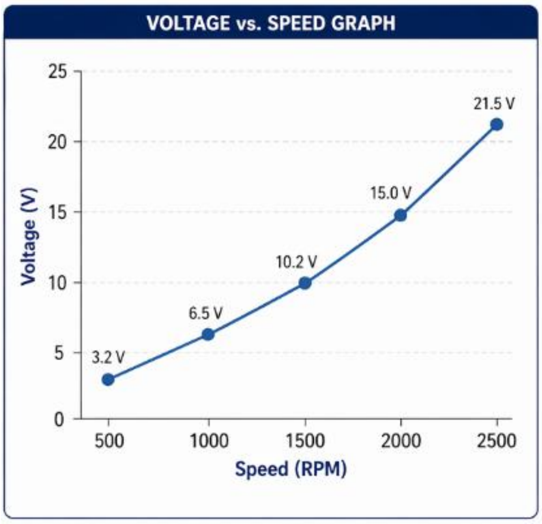


Figure 4.2: Speed (Rpm) Vs Voltage (V) Relationship Graph

Graph analysis shows the relationship between RPM and voltage is almost linear, proving the performance of the generator is stable under various operating conditions. A more significant increase in power at high speeds indicates that the efficiency of the system increases as the kinetic energy supplied increases. Overall, these findings prove that Smart KERS-Kit works well from a technical point of view and is able to display real-time data that helps students understand the concept of energy conversion more clearly. Stable system integration and consistent energy conversion performance make this kit a high-potential innovation in improving the effectiveness of engineering field teaching and learning.

5. DISCUSSION

The findings of the first objective show that the effectiveness of the Smart KERS-Kit integration is influenced by the relationship between the mechanical, electrical components and the microcontroller control system. The movement of the DC motor produces kinetic energy that is converted into electrical energy by the generator, in line with the principle of energy conversion. The efficiency of the system depends on rotational stability, component alignment, reduction of energy loss, sensor accuracy, and the ability of microcontrollers to process real-time data. For the second objective, the findings show a linear relationship between the motor rotation speed and electrical output, where an increase in RPM results in a consistent increase in voltage and power. Overall, Smart KERS-Kit has proven to work stably, helping users understand the concept of energy conversion through real-time data display, as well as potentially being an innovative teaching aid in engineering education.

6. CONCLUSION

Overall, the development of Smart KERS-Kit has successfully proven its effectiveness as an innovative pedagogical tool that connects hybrid automotive theory concepts with practical applications in an interactive manner. Through the use of Arduino microcontrollers and real-time telemetry displays, the prototype was able to demonstrate the relationship between motor speed and power generation and help improve the engagement, practical skills and conceptual understanding of TVET students. In addition to bridging the gap between academic learning and industry needs, these innovations also support the global sustainability agenda through exposure to clean energy technologies and climate mitigation. In the future, Smart KERS-Kit can be improved with the integration of the Internet of Things (IoT), mobile applications and artificial intelligence (AI)-based controls. In conclusion, Smart KERS-Kit has the potential to be a strategic transformation in automotive education to produce competitive and green technology-literate human capital.

Acknowledgments: The writer would like to express his deepest appreciation to his beloved spouse and children who have always provided moral support, encouragement and patience throughout this research and writing process. Gratitude is also addressed to the Politeknik Kota Bharu for the academic support, facilities and guidance that have been provided throughout the study period. In addition, appreciation is also given to all colleagues, lecturers, and individuals who have helped directly or indirectly in the success of this study. All the help, insights and cooperation given are greatly appreciated and are the catalyst for the success of this writing.

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