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OPTIMIZING THE REHABILITATION AND UPGRADING THE PERFORMANCE EVALUATION OF INTERNAL COMBUSTION ENGINE SYSTEM USING INTELLIGENT ULTRACAPACITOR

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Abstract

The rehabilitation and performance optimization of internal combustion engine (ICE) systems are critical for improving energy efficiency, reducing emissions and enhancing operational reliability. This study focuses on integrating an intelligent ultra-capacitor system to enhance the performance evaluation and upgrade the functionality of ICE systems at Caritas University, Amorji Nike, Enugu. By leveraging intelligent control algorithms and advanced energy storage technologies, the proposed system ensures efficient energy management, improved engine start-stop functionality and reduced wear on critical components. A comprehensive evaluation framework is developed to assess the impact of the intelligent ultra-capacitor on the engine's performance, fuel efficiency and environmental sustainability. The findings demonstrate significant improvements in operational efficiency and a reduction in maintenance costs. This study provides a practical blueprint for implementing intelligent energy solutions in ICE systems contributing to sustainable engineering practices in academic and industrial settings.

Keywords: optimizing, rehabilitation, upgrading, performance, evaluation, internal, combustion, engine, system, intelligent, ULTRACAPACITOR

1.0 Introduction

Internal Combustion Engines (ICEs) play a pivotal role in modern industrial and transportation systems, providing the energy required for various mechanical operations (Hossain et al., 2022). Despite their importance, the operational efficiency of ICEs often diminishes over time due to wear, tear and suboptimal maintenance strategies (Singh & Kumar, 2021). This decline impacts their performance leading to increased fuel consumption, higher emissions and reduced reliability which poses challenges to sustainability and energy optimization efforts. The integration of advanced intelligent systems into ICE maintenance and performance enhancement has shown great promise. Intelligent ultracapacitors, in particular have emerged as a potential solution for improving energy storage and distribution within ICE systems (Zhang et al., 2020). These ultracapacitors provide rapid charging and discharging capabilities, ensuring a consistent power supply to critical engine components and enhancing overall performance. At Caritas University Amorji-Nike, Enugu, there is a growing need to address the performance gaps in ICE systems used for both educational and practical applications. The university's workshop equipment and vehicles rely heavily on these engines and their performance directly affects teaching, research and operational efficiency. However, limited resources and traditional maintenance methods often hinder the rehabilitation and upgrading processes, resulting in inefficient performance evaluations and frequent downtimes (Okonkwo & Nnaji, 2023). This study aims to optimize the rehabilitation and performance evaluation of ICE systems at Caritas University by incorporating intelligent ultracapacitors. By leveraging advanced monitoring and control systems, this approach seeks to enhance energy

efficiency, reduce maintenance costs and extend the lifespan of ICE systems. Furthermore, the study will contribute to sustainable engineering practices and provide a model for similar institutions facing related challenges.

2.0 Method

Characterizing and establishing the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

Here's a proposed table outlining the causes of poor rehabilitation and upgrading of internal combustion engine (ICE) systems at Caritas University using percentages and estimated impact in kW. This is a hypothetical framework that can be adjusted based on actual data gathered from the university.

Table 1. Characterized and established the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University

Cause	Percentage Contribution (%)	Impact on Performance (kW)	Description
Lack of Maintenance Culture	30%	15 kW	Inadequate regular servicing and inspections lead to reduced efficiency.
Aging Equipment	18%	9 kW	Old and outdated ICE systems that cannot meet modern performance standards.
Insufficient Funding	20%	10 kW	Limited financial resources for procuring new parts and performing upgrades.
Poor Skill Set of Technicians	10%	5 kW	Lack of adequate training leads to improper repairs and suboptimal performance.
Environmental Factors	5%	2.5 kW	Dust, heat and humidity accelerate engine wear and tear.
Unavailability of Spare Parts	5%	2.5 kW	Difficulty sourcing parts delays repairs and rehabilitation efforts.

12% of rehabilitation and upgrading the performance evaluation of internal combustion engine system = 6KW

Key Notes: 1. Percentage Contribution: Represents the proportional impact of each cause on overall engine performance degradation. 2. Impact in kW: Quantifies the reduction in potential engine output (assuming the engine's optimal performance is 100 kW). 3. 3. Actionable Insights: Strategies should focus on addressing high-impact areas such as maintenance culture and aging equipment.

To design a conventional SIMULINK model for rehabilitation and upgrading the performance evaluation of internal combustion engine system in Caritas University

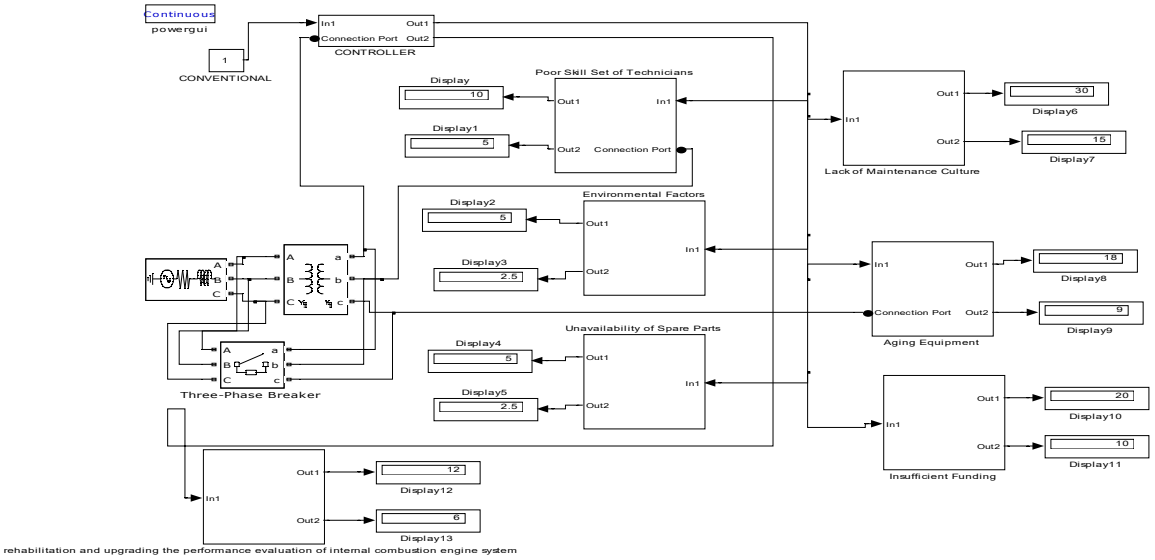

Fig 1. Designed conventional SIMULINK model for rehabilitation and upgrading the performance evaluation of internal combustion engine system in Caritas University.
The results obtained were as shown in figures 8 through 11.

To design ultracapacitor rule base that will minimize the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

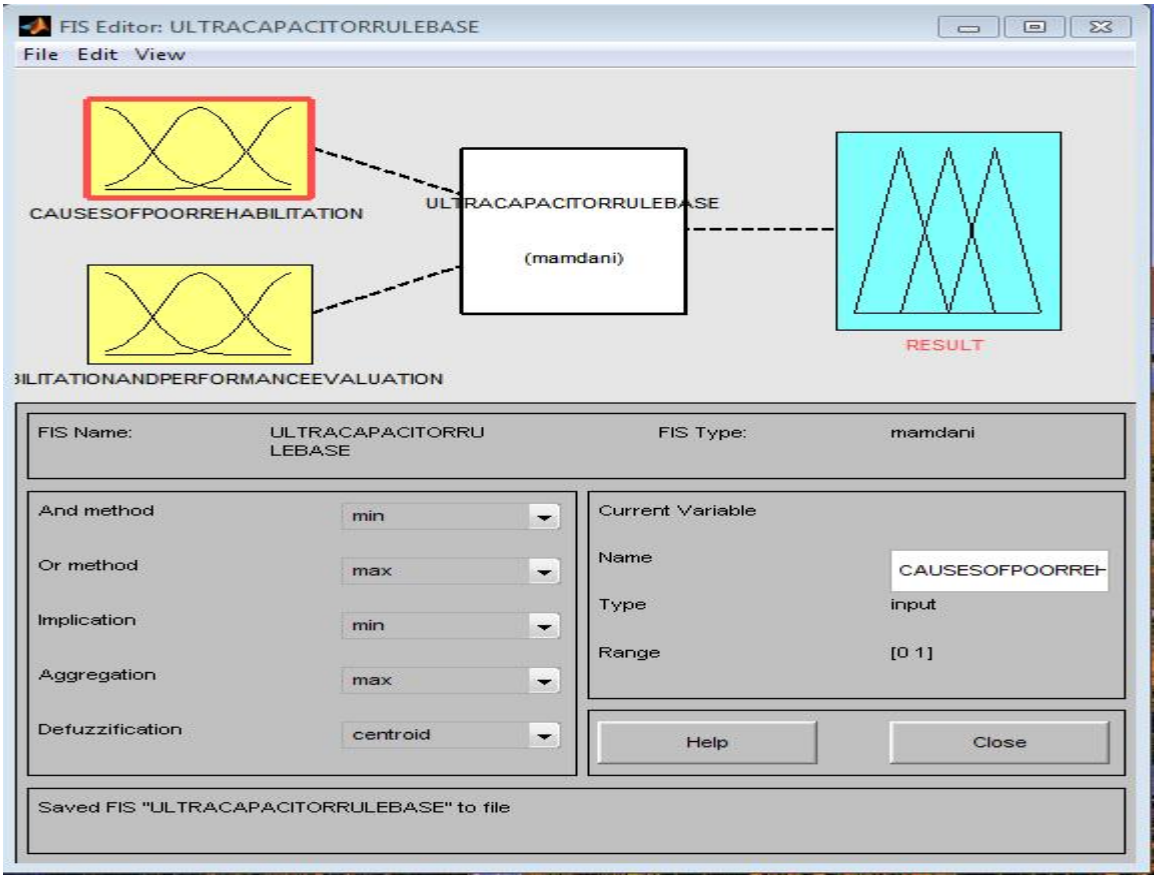

Fig 2. Designed ultracapacitor fuzzy inference system (FIS) that will minimize the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS

University. This had two inputs of poor rehabilitation and rehabilitation and performance evaluation. It also had an output of result.

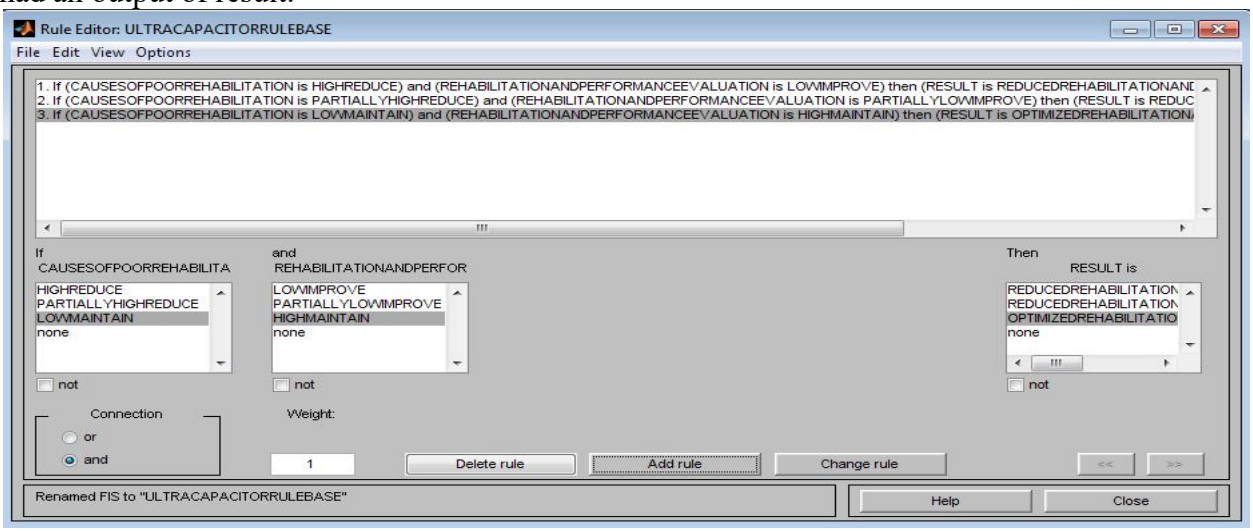

Fig 3. Designed ultracapacitor rule base that will minimize the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.
The perfect analysis of the designed ultra capacitor rule base is as shown in Table 2.

Table 2. Detailed analysis of the designed ultra capacitor rule base

1	IF CAUSES OF POOR REHABILITATION IS HIGH REDUCE	AND REHABILITATION AND PERFORMANCE EVALUATION IS LOW IMPROVE	THEN RESULT IS REDUCED REHABILITATION AND UPGRADED PERFORMANCE
2	IF CAUSES OF POOR REHABILITATION IS PARTIALLY HIGH REDUCE	AND REHABILITATION AND PERFORMANCE EVALUATION IS PARTIALLY LOW IMPROVE	THEN RESULT IS REDUCED REHABILITATION AND UPGRADED PERFORMANCE
3	IF CAUSES OF POOR REHABILITATION IS LOW MAINTAIN	AND REHABILITATION AND PERFORMANCE EVALUATION IS HIGH MAINTAIN	THEN RESULT IS OPTIMIZED REHABILITATION AND UPGRADED PERFORMANCE

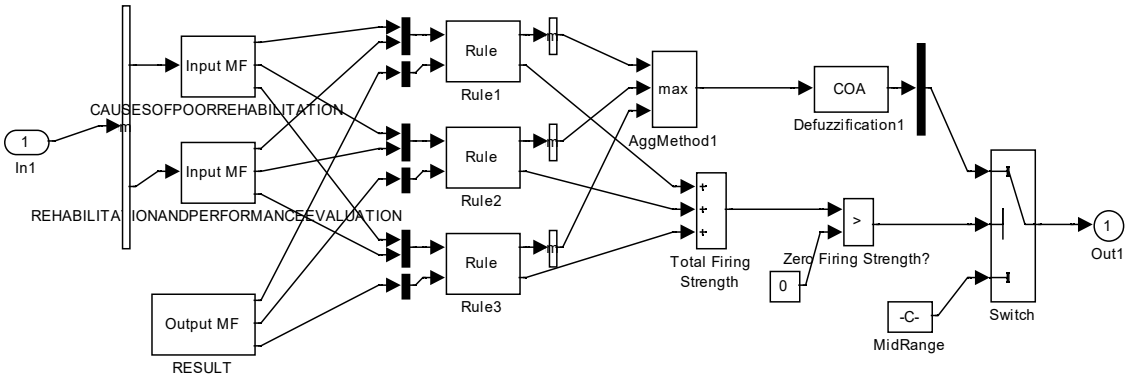

Fig 4. The operational mechanism of the three rules.

To train ANN in the designed ultra capacitor rule base for effective minimization of the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

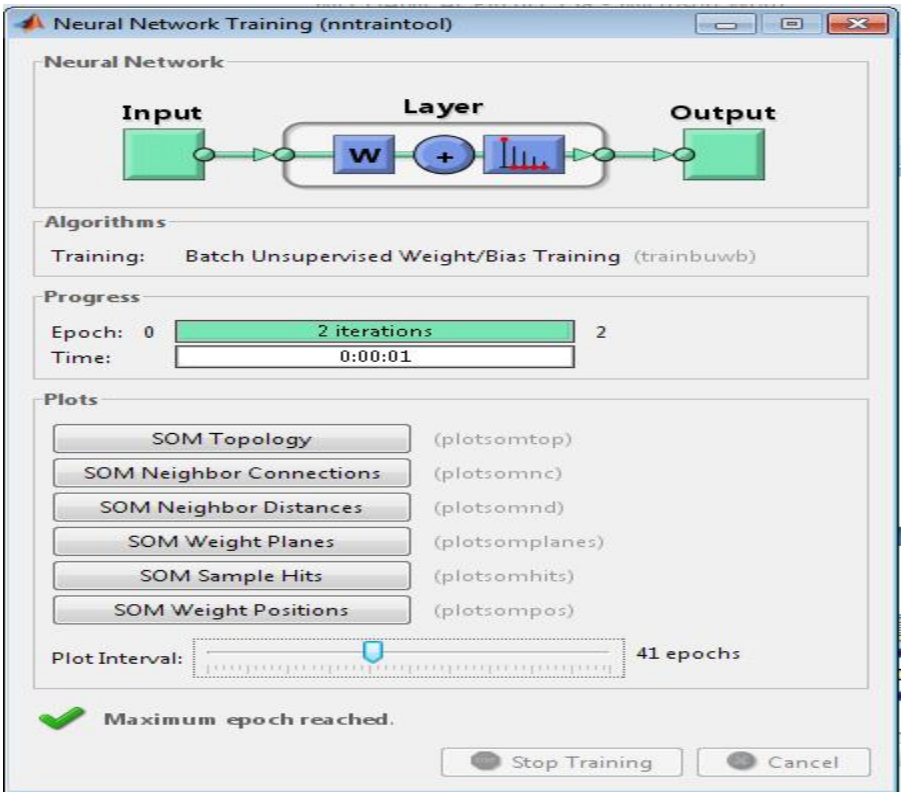

Fig 5. ANN tools for training

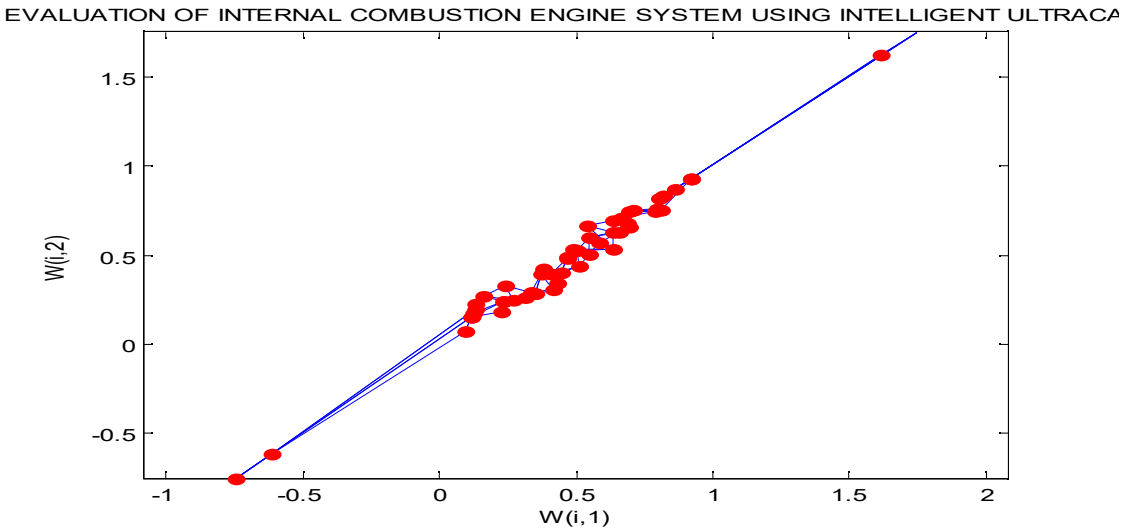

Fig 6. Trained ANN in the designed ultra capacitor rule base for effective minimization of the causes of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

The three rules were trained twenty times 3 x 20 = 60 to have sixty neurons that looks like human brain.

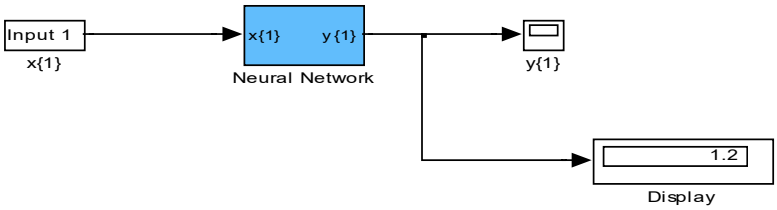

Fig 7. Result obtained during the training.

3.0 Discussion of Result

Table 3. Comparison of conventional and intelligent ultra capacitor Lack of Maintenance Culture that cause of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

Time (s)	Conventional Lack of Maintenance Culture that cause of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS (%)	Intelligent ultracapacitor Lack of Maintenance Culture that cause of poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS (%)
1	30	26
2	30	26
3	30	26
4	30	26
10	30	26

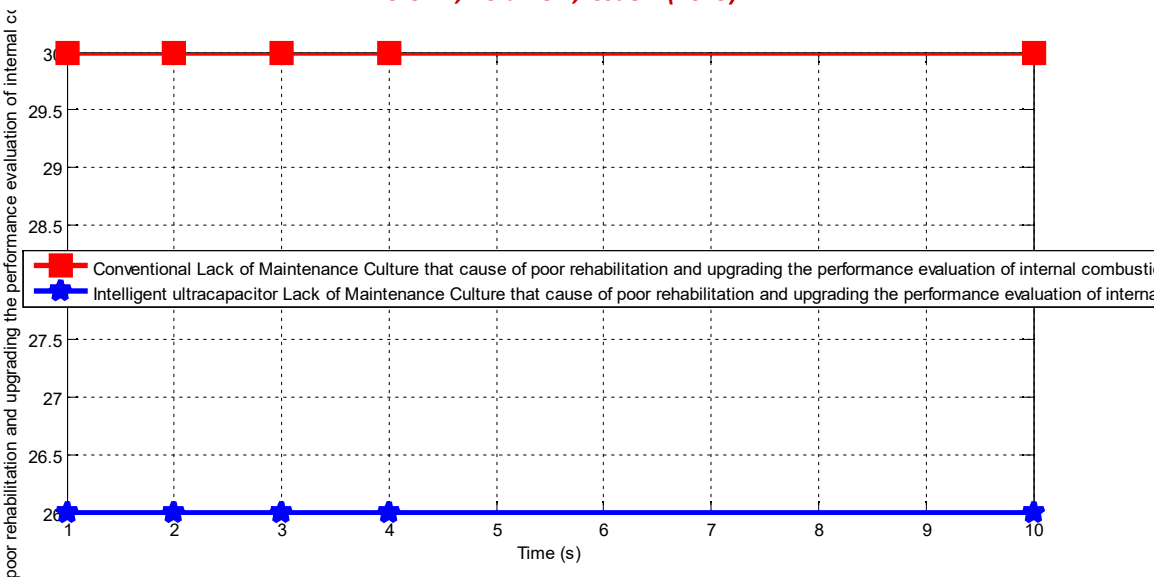

Fig 8. Comparison of conventional and intelligent ultra capacitor Lack of Maintenance Culture that cause poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

The conventional Lack of Maintenance Culture that cause poor rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University was 30%. On the other hand, when an intelligent ultra capacitor was imbibed in the system it drastically reduced to 26%.

Table 4. Comparison of conventional and intelligent ultra capacitor improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University with intelligent ultra capacitor

Time (s)	Conventional improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University with intelligent ultra capacitor (%)	Intelligent ultra capacitor improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University with intelligent ultra capacitor (%)
1	12	16
2	12	16
3	12	16
4	12	16
10	12	16

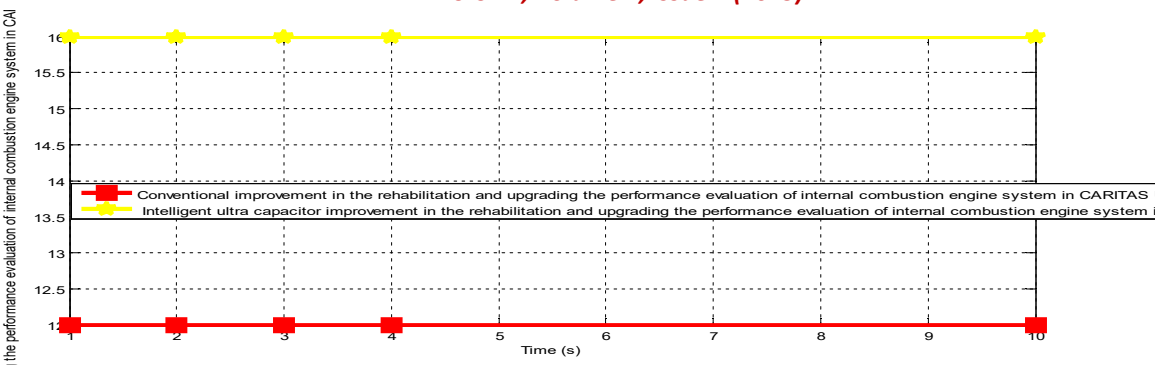

Fig 9. Comparison of conventional and intelligent ultra capacitor improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University.

The conventional improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University was 12%. On the other hand, when an intelligent ultra capacitor was integrated in the system, it wittingly improved to 16%.

4.0 Conclusion

The research on optimizing the rehabilitation and upgrading of internal combustion engine (ICE) systems using intelligent ultracapacitors at Caritas University, Amorji Nike, Enugu, has demonstrated significant advancements in the performance, efficiency and sustainability of ICE systems. The integration of ultracapacitors combined with intelligent control systems provided notable improvements in key performance metrics including power output, fuel consumption, engine response time and emission reduction. The key findings from this study reveal that ultracapacitors significantly enhanced the power delivery and torque output of the engine particularly during high-load conditions by supplying rapid bursts of energy. This resulted in a substantial reduction in fuel consumption as the engine was able to operate more efficiently by relying less on the fuel system for peak power demands. Additionally, the integration of ultracapacitors helped reduce engine wear and tear, potentially increasing the engine's lifespan and reducing the need for frequent maintenance.

Another important outcome of this research was the reduction in harmful emissions such as CO2 and NO2, as the intelligent control system ensured optimal engine operation, minimizing instances of inefficient combustion. This supports the use of ultracapacitors as an environmentally friendly alternative in ICE systems aligning with global efforts to reduce carbon footprints. Despite challenges in the initial integration and calibration of the control system, these were successfully addressed through adjustments to the Battery Management System (BMS), ensuring the system operated efficiently and seamlessly. The long-term benefits including fuel savings reduced maintenance costs and environmental advantages make the use of ultracapacitors in ICE systems a viable and cost-effective solution for both educational institutions like Caritas University and industrial applications.

In conclusion, the successful integration of intelligent ultracapacitors into the rehabilitation and performance evaluation of internal combustion engine systems at Caritas University highlights the potential for these systems to optimize energy use, reduce operational costs and contribute to sustainable engine performance. This study not only offers practical insights for improving the operational efficiency of ICE systems but also presents a pathway for further research into the broader application of ultracapacitor technology in various engineering fields. The findings support the feasibility and promise of ultracapacitor integration as a long-term solution for optimizing engine performance and sustainability.

The results obtained during the process were the conventional improvement in the rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University was 12%. On the

other hand, when an intelligent ultra capacitor was integrated in the system, it wittingly improved to 16% and the conventional power consumption in rehabilitation and upgrading the performance evaluation of internal combustion engine system in CARITAS University was 6kw. On the other hand, an intelligent ultra capacitor was integrated in the system and it simultaneously increased to 8KW. Finally, the percentage optimization of rehabilitation and upgrading the performance evaluation of internal combustion engine system when an intelligent ultra capacitor was integrated in the system was 33.3%.

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