SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V12I3P110
Volume 12 Issue 3, 92-99, March 2025

Original Article

Design of an Automated System for the Benefit of Energy Consumption and Control of Industrial Equipment with Artificial Intelligence

Laly Gabriel Quispe Cuti[1], Lady Sofia Quispe Choquejahua[2], Raúl Ricardo Sulla Torres[3]

[1,2,3]Universidad Nacional de San Agustín de Arequipa, Arequipa, Perú

[1]Corresponding Author : lquispecuti@unsa.edu.pe

Received: 24 December 2024 Revised: 14 March 2025 Accepted: 20 March 2025 Published: 31 March 2025

Abstract *- This article shows the design and evaluation of an automated system capable of performing monitoring functions of critical parameters of work and operation in the industrial metal mechanical sector; the implementation arises due to the need to increase production and efficiency in terms of saving power supply for the use of stationary machines and power tools with high amperage consumption. A system will be put into operation which was designed based on the acquisition of data obtained by the control circuits of each corresponding area, data obtained through a camera with AI, obtaining data such as electric current used while performing the work, calculation of current according to the work cycle of each equipment, maintenance program and short circuit due to unexpected electronic failures, The evaluation of this system guarantees significant savings in power supply due to standby time in stationary equipment and tools in the metal-mechanical sector and can be expanded to other industrial sectors.*

Keywords *- Smart home automation, Energy consumption optimization, Internet of Things (IoT), Artificial Intelligence (AI), Predictive Maintenance*

1. Introduction

In recent years, the metal-mechanical sector in Peru has become a reliable and competitive supplier at the industrial level due to the recognition obtained due to the mass production of metal components and structures, the innovation of mechanical manufacturing strategies, the use of advanced technologies for structural purposes and the use of modern equipment make it a competitive and fast-growing sector. Implementing an automated system capable of reducing the energy consumption of stationary equipment and electric tools is proposed, with functions of monitoring working hours, maintenance program, calculation of current consumed during the work and short circuits due to internal equipment failures. This system aims to reduce monthly energy consumption and increase equipment efficiency because it has functions such as predictive and scheduled maintenance, since it has sensors and respective data of anomalies evaluated by artificial intelligence as applied in [4], avoiding that these types of equipment can present failures due to lack of such maintenance. The detection of operators working in the place and use of the equipment with the respective system will be monitored by artificial intelligence through an integrated camera, which will allow the acquire variables which are fundamental for the decision-making of the proposed system. The main advantage of this system is its ability to perform a real-time analysis of the operating parameters of the equipment, identifying energy consumption patterns and adjusting the operating cycles according to actual production needs.

The artificial intelligence application allows the implementation of optimization algorithms that dynamically adjust the operation of industrial equipment to reduce unnecessary energy consumption and improve the energy efficiency of the area to be implemented. This system is adaptable to various industrial sectors, such as the automotive, food, agricultural and pharmaceutical industries, as it can be easily integrated with various equipment and devices, improving control over energy consumption and contributing to companies' sustainability. Implementing this system reduces energy expenditure and optimizes resources [6], decreases operating costs and improves competitiveness, resulting in a more energy-efficient and responsible operation.

This study focuses on designing and evaluating an advanced domotic system to control and optimise energy consumption in industrial equipment to reduce energy expenditure and improve operational efficiency in production environments. The proposed system uses technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to monitor, manage and control industrial equipment in an automated way, adjusting its operation in real-time to minimize energy consumption without compromising the performance and productivity of the industrial metal-mechanical sector.

2. Related Works

The implementation of IoT systems and artificial intelligence in different industrial sectors are feasible technological solutions for obtaining required needs such as selection and evaluation of procedures as the case of [1], where IoT is used as learning for different systems for control and monitoring, applied for SM intelligent manufacturing, analyzing safety factors, predictive maintenance, process control, additive manufacturing and data analysis strategies.

Likewise, in [2] where they use iot as a protection system against security breach threats in the oil industry, where the care of very relevant and influential data in the production of such materials, using systems such as LSTM and CM communication modules to perform such functions in terms of its first application described to corroborate and prevent data leakage, in [3] shows a condition monitoring scheme using industrial IoT which proposes a learning network for intelligent manufacturing which can be impaired by external and complex factors, such as sensor failures or unexpected interruption of data transmission to which to give a predictive before a loss in its entirety, showing a qualified information as defective and performance in its monitoring, in [4] facing the challenge of improving efficiency and stability in industrial processes integrates the Iot and AI to an integrated system by PLC and HMI obtaining results of 22. 85% in efficiency, stabilizing production and reducing process variability, obtaining significant results for learning processes programmed by software such as TIA PORTAL and PLC SIM, promoting operational quality and efficiency in industries, in [5] AI-based predictive maintenance is used for industrial IoT control systems using machine literacy algorithms and data analysis in real-time allowing interventions to be carried out promptly and at a cost-effective level, where successful implementations are also shown where practices used with IoT and AI can transform conventional situations, driving significant advances in reliability and productivity, in [6] talks about the improvement that IoT had in industrial engineering, to increase productivity and reduction of operating expenses, achieving combined human and mechanical work.

The adoption of automated technology for modern manufacturing, AI provides relevant information about errors and possible failures, analyzing the interconnection and integrated technologies in different industrial devices. In [7], integrating IoT with artificial intelligence in the cloud is essential to transform industrial systems. In the specific case of Bosch, this technological convergence plays a crucial role in the optimization of manufacturing processes and supply chain management as well [8]; the system integrates transportation management, identification of optimal routes, real-time monitoring of critical vehicle parameters and predictive maintenance, which ensures a more efficient operation of the supply chain. The results obtained show an improvement of 77% to 98% in overall system performance. In addition, a considerable increase in operational efficiency, customer satisfaction and a reduction in operational costs were observed, all with energy-efficient and low latency performance, strengthening the company's competitiveness and profitability.

In [9], results are proposed using IoT devices with a ventilation KPI (KPIv) adapted to Smart Cities and specifically designed for academic environments such as Smart Universities, where community members spend long periods in enclosed spaces. The KPIv focuses on estimating the number of occupants and CO_2 accumulation in these spaces, using regressive neural networks to perform the estimations. These networks were integrated into small, inexpensive IoT devices connected through a low-power LoRa network. Regarding detecting people and other variables in [10], the study proposes an IoT and AI-enabled automated entrance monitoring system, which integrates an RFID reader to count people and verify the use of face masks in crowded places, such as shopping malls, stadiums and train stations.

The system also measures the body temperature of individuals using thermal sensors, providing a fever detection mechanism. Without the need for manual intervention, this cost-effective, electronic solution operates autonomously, optimizing access control and reducing the risk of COVID-19 transmission in public environments while minimizing the labor costs associated with verifying health and safety measures.

To conclude in [10], a two-level AI-based genetic algorithm is proposed for the health monitoring agricultural vehicles, using smartphones with integrated microphones instead of expensive IoT sensors. This solution optimizes edge computing to handle large volumes of real-time data, reducing network and cloud storage overhead. The approach offers a cost-effective and efficient option, enabling monitoring agricultural machines with low latency and high emergency responsiveness, all managed locally on mobile devices.

3. Methodology

This article presents the development, design and evaluation of an automated system with artificial intelligence for the industrial metal mechanical sector to reduce energy consumption in industrial equipment such as stationary machines and power tools (See Figure 1). The purpose of this development arises due to high energy consumption, poor control and management of the use of this equipment; the main features of this system are:

- Control and management of energy consumption in stationary machines and power tools.
- Monitoring of working hours to limit the use of equipment lacking maintenance.
- The maintenance program for each piece of equipment exceeded the working time limit according to its detected consumption.
- Calculate the current consumed in each electrical outlet and verify compliance with the duty cycle.
- Short-circuit detection in electrical distribution outlets.
- Dimensions of 10cm x 5cm x 8cm and weight 0.2 kg.
- Low implementation and manufacturing costs.
- It has an OV2640 camera for detecting the operator and a PCB control based on the ESP32-CAM microcontroller for the system's logic.
- The controller was adaptable to any electrical or electronic system for load control.

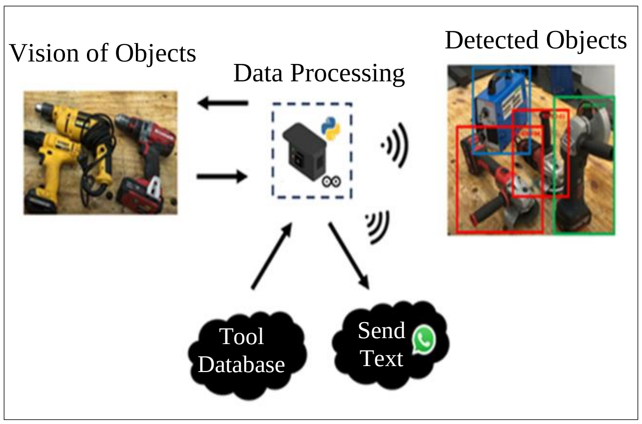

Fig. 1 Processing and selection of objects

The design of the case for the protection of the control PCB was made in AUTOCAD 3D software, which has attachment points to be installed at a suitable height on the wall of the area to be implemented, mobility in the OV2640 camera for a more precise focus and cover for protection from sun and dust. The dimensions of the control module will be 10cm*5cm*8cm(length*width*height) (see Figure 2). For the correct implementation of AI, data acquired from KPI measurements and monitoring indexes of the equipment were considered, along with the logistics responsible for providing this information. The PYTHON programming language and ARDUINO ID software were utilized, incorporating the YoloV8 architecture to enhance the identification of existing tool types, ensuring greater accuracy and robustness in selection through artificial vision. By integrating a neural network into the ESP32, tool classification and location assignment within designated areas were achieved. This process requires a standardized location system for equipment placement, such as welding and roughing areas, and the classification of equipment based on function, 250A or 425A welding equipment, three-phase or single-phase, and appropriate operator clothing to ensure process safety.

4. Developed System

The electronics in the system are divided into 2 stages; in addition to including the electrical part in its implementation, the control PCB performs the discrete control according to obtaining variables obtained as amperage, positioning or short circuit by failure in the equipment. The second electronic stage is included in the board, where the control voltages of 24V are for the control of auxiliary relays, and 24V is an independent power supply for the system control PCB.

Fig. 2 Control module

4.1. Electronics of the Domotic System

The design of an electronic control PCB was made, where an ESP32-CAM is used as the main microcontroller of the control PCB, 8 inputs or outputs are obtained from this PCB, which will be used 4 for output control and 4 for input control, outputs are discretely using active components such as MOSFET's to control auxiliary relays for more optimal control in its power stage of the system, The inputs are analog, to obtain variables such as current in its three-phase and single-phase derivation (see Figure 3), for this purpose, a non-invasive sensor was selected as the current sensor SCT-013-100, which offers a reading of 50mA for every 100A of consumption per line. The programming was done in the ARDUINO IDE software, an open-source program that is very friendly in programming with the C++ language. The PYTHON software integrates machine vision and selection between objects and data transmission to supervision through a bot with password protection, which makes it robust to possible leaks; artificial intelligence implemented in the device allows for evaluation of the positioning of the operator and evaluate the situation or action to be performed.

4.1.1. Welding Area

The position in which the equipment is located, either 250A or 425A; in this case, the amperage variable used is evaluated since it is an inverter that performs little consumption compared to transformer equipment. According to its characteristic table for a 125Amp work, the inverter consumes 17Amp per single phase line and 5Amp per three-phase line, as for the transformer equipment at the same amperage it consumes 28Amp per single phase line and 12Amp per three-phase line, these values were corroborated and measured with a Fluke 375 amperimetric clamp. The system obtains these amperage variables thanks to the sensors implemented in its distribution lines, and the corresponding action is performed, enabling the corresponding contactor and generating the timer of use, which for this equipment is 500 hours until receiving new maintenance (see Figure 4).

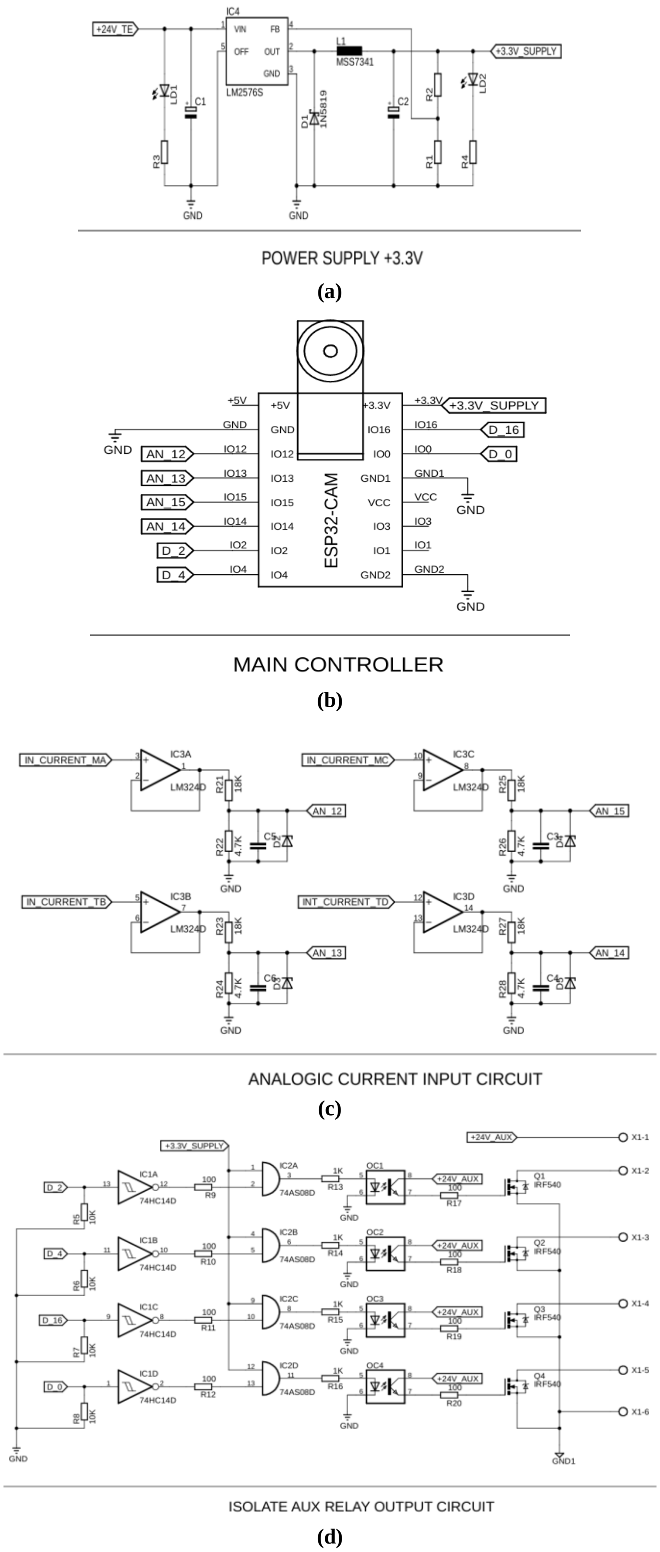

Fig. 3 Electronic schematic of the control PCB

Since values of amperage, consumption per equipment and timing are obtained, the control PCB performs the necessary calculation to perform the programming of the next maintenance, possible failures due to high consumption problems or possible premature repairs due to excess of the work cycle and even failures due to short circuit blocking the power supply.

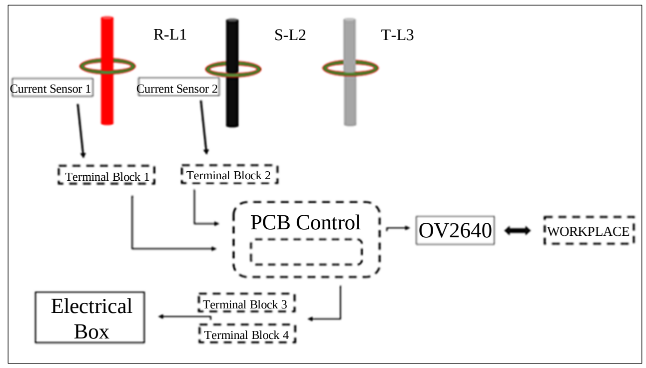

Fig. 4 Block diagram of control PCB operation

4.2. Control Electronics in Electrical Board

The use of artificial intelligence in the system performs the recognition of the operator in area position, to perform the discrete logic for load activation and data acquisition described in its main characteristics. The design and simulation of the control PCB were performed in the EAGLE and PROTEUS software, where the operation is corroborated before being implemented; the first test of operation was performed with the current sensing in the three-phase and single-phase derivation of the electrical panel of the equipment to be connected; using the ESP32-CAM module is achieved to perform this recognition of the operator mentioned for the decision making of the electrical panel allowing the enablement of contactors inside the panel.

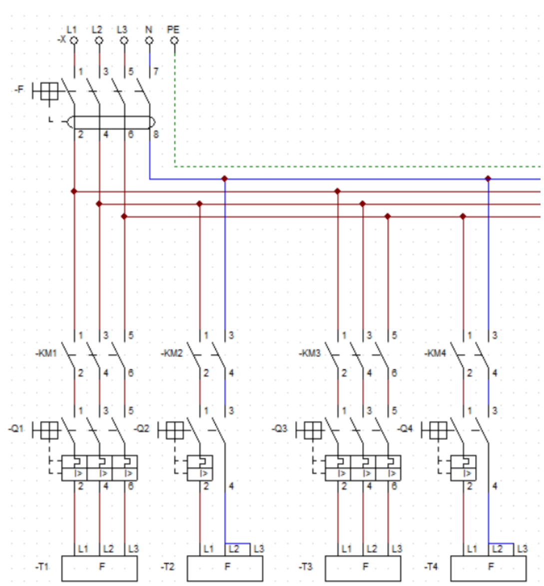

Fig. 5 Electrical diagram of the electrical panel operation

The contactors used were required according to the load that can be obtained in the equipment or electrical tools; these are 40Amp for single-phase inverter NCH8-40 CHINT brand and 63Amp for single-phase transformer equipment NCH8-63, both single-phase contactors 230V control coil, As for the three-phase contactors, the three-phase contactor NC1-6511 of the CHINT brand for three-phase transformer welding equipment and NC1-4011 for three-phase inverter equipment, which is controlled by 4 auxiliary relays governed by the control PCB from the system (see Figure 5), for the design of the electrical panel was used the CADE SIMU software in which the diagram of force to be controlled was made.

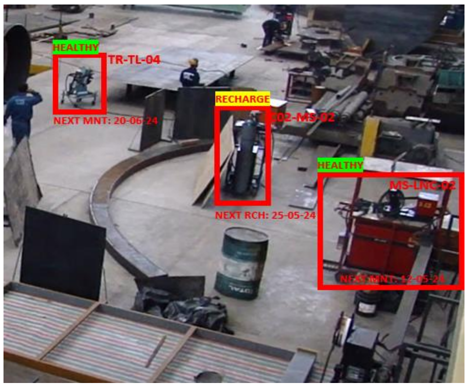

Fig. 6 View of ESP32-CAM in reception

Finally, the use of wifi built into the equipment in this system gives us the facility to send messages via text to the supervisor in charge via WhatsApp through the code made in PYTHON and the use of a private bot; when the equipment is being used, you can view its status and basic conditions and at the end of the day will be given detail in depth as use amount of equipment used, hours on, overcoming duty cycle, upcoming maintenance (see Figure 7), which is why this system is practical and efficient in terms of equipment management and energy savings, thus ensuring greater control of the energy to be used in the industry compared to equipment that is relatively on all day generating excessive consumption due to its waiting times.

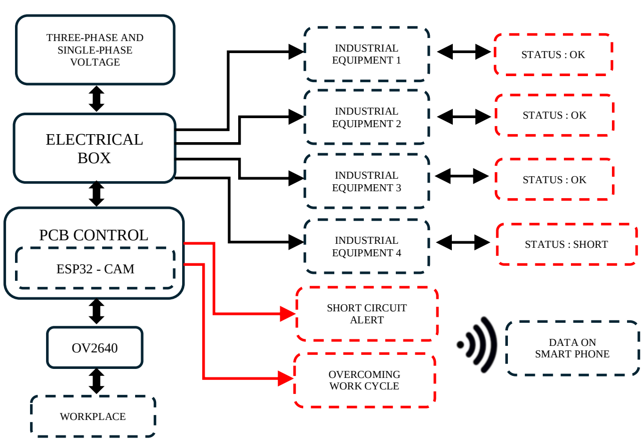

Fig. 7 Block diagram of operation of sending data by equipment status to supervision

The artificial intelligence incorporated in the ESP32 will activate or deactivate its power stage when the equipment malfunctions, alert for exceeding duty cycle and location found, thus providing the respective information of probable causes for prompt repair or maintenance, a "HEALTHY" status is displayed when the equipment is without demand for use (See. Figure 6), as opposed to the "OPERATING" or "RECHARGE" status when the equipment is in use, or an accessory is missing in the equipment to be used (See Figure 8).

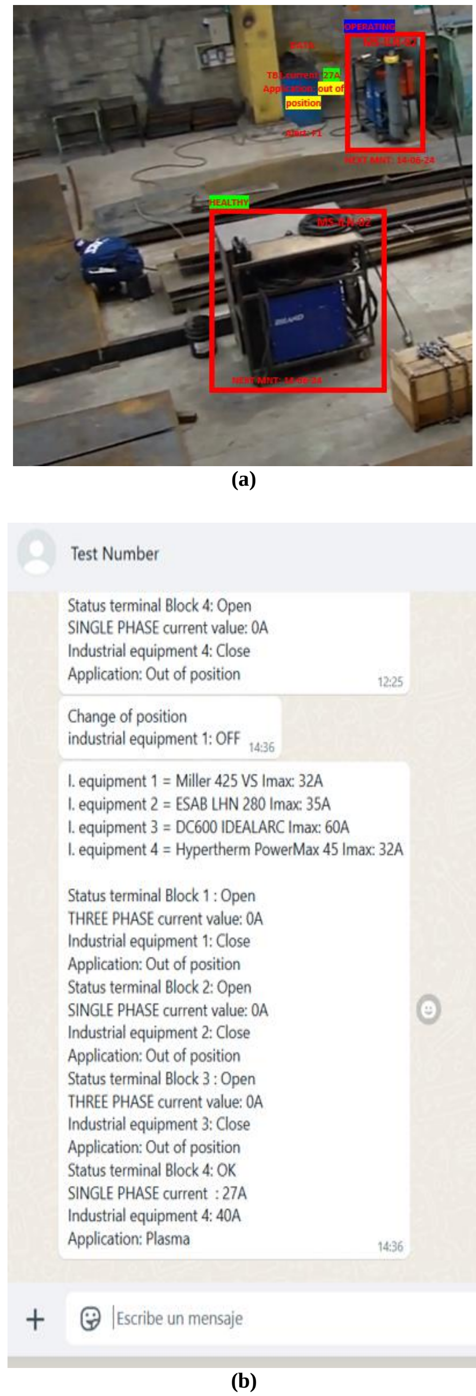

Fig. 8 Sending data by text to the supervisor in charge of the area

5. Test and Results

To evaluate the effectiveness of the automated system, it was implemented in a real operating environment in a metal-mechanical company located in the industrial park of Cerro Colorado, Arequipa, where performance and effectiveness tests were carried out in terms of the energy savings proposed in the design. The monitoring was carried out during a period of 3 months, obtaining results of considerable energy savings, in addition to better management and control of their equipment, based on energy data from receipts and KPIs of management by supervision. The operation of the contactors and modules themselves was evaluated, obtaining components and designs to be improved, such as dust protection in the chamber, ventilation in the control module or PCB and the blocking of industrial plugs to prevent their disconnection.

Likewise, data such as amperage readings per phase corresponding to the distribution of three-phase and single-phase lines were evaluated, obtaining an offset of less than 5% from an initial calibration due to wear or overheating in conductors (See Figure 9), as the sending of data corresponding to the operations performed by the operator in charge, power components such as contactors evaluating their wear and a comparative control to the considerable savings in energy consumption calculated by the system. The comparison made was given by different equipment used on average, in which the production has been increasing during the last months in that company; therefore, the evaluation was made empirically and with data obtained by the system that validates its efficiency in terms of equipment use and energy savings according to stored KPI's indexes (see Figure 9).

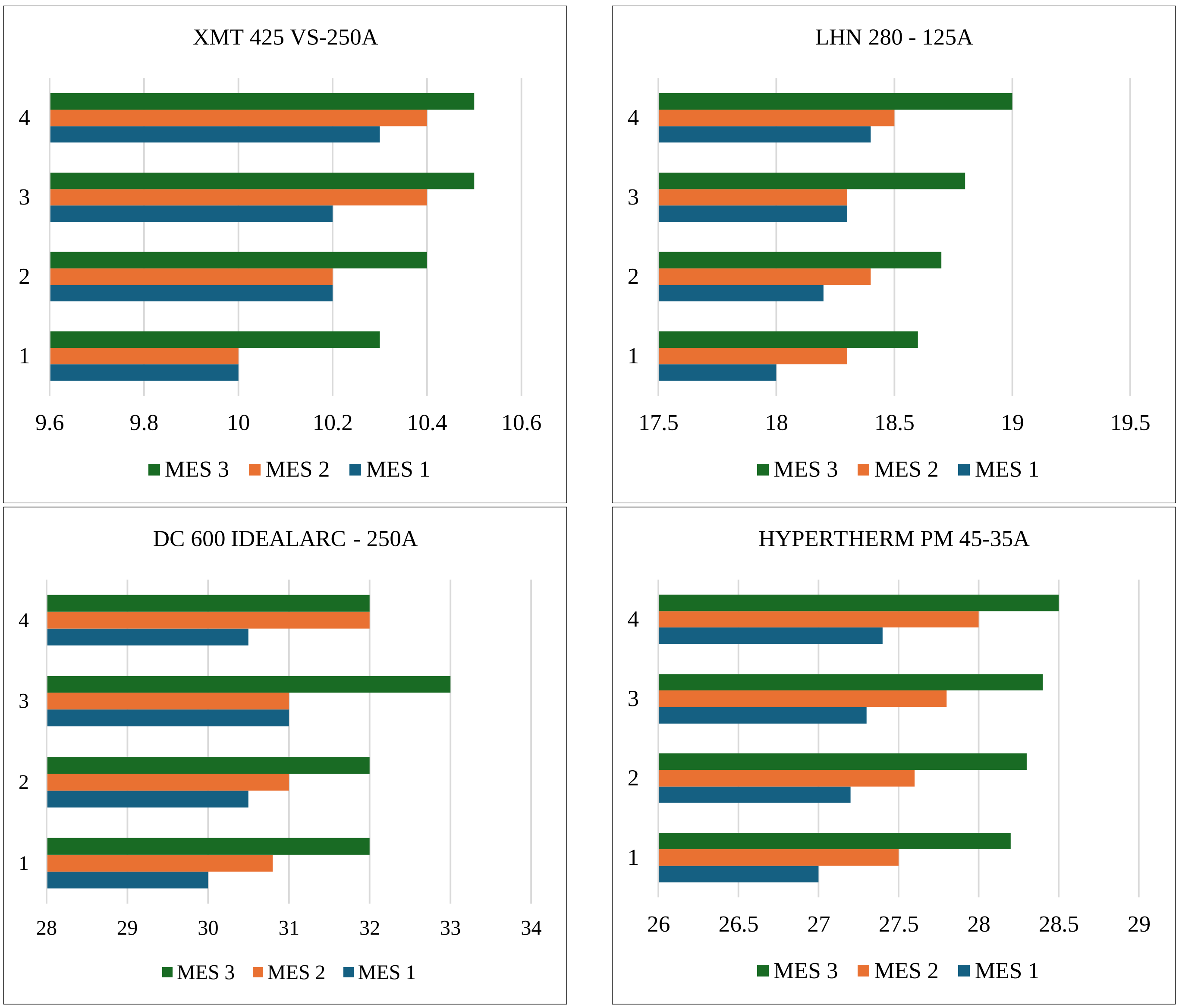

Fig. 9 Phase shift by equipment during the last 3 months

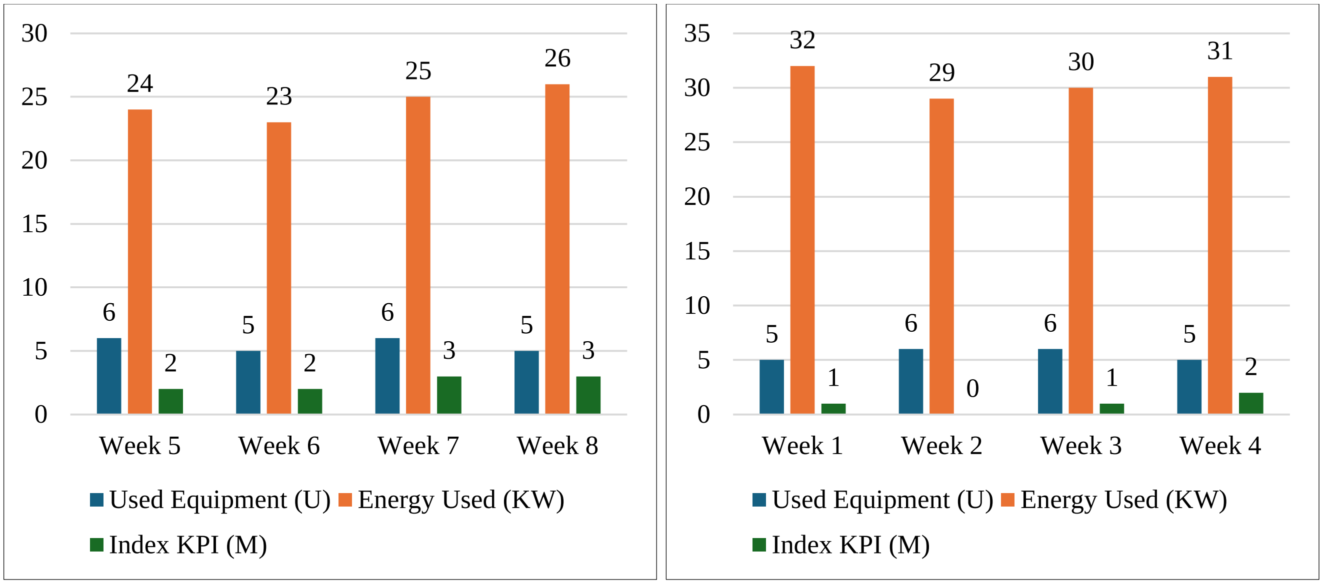

Fig. 10 Weekly comparison by consumption, energy and KPI's

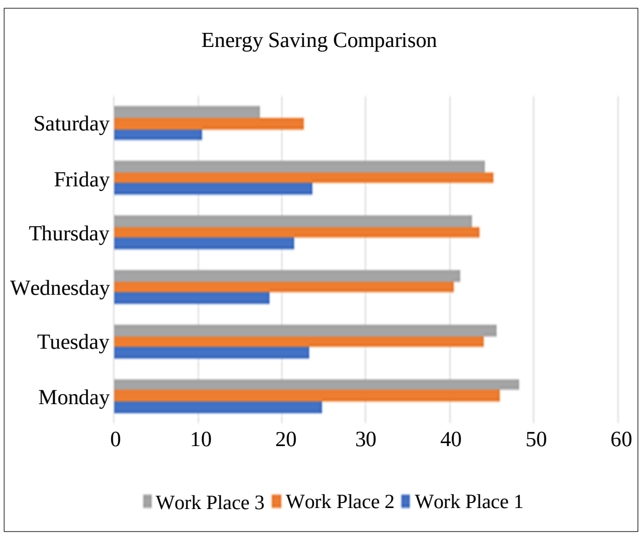

Fig. 11 Weekly comparison by consumption

Additionally, it was evaluated to consider data such as consecutive working hours by the operator in charge, where it was compared the control that could have one who has the integrated system on their equipment and one who does not have it in a pilot week period, the comparisons were made with 3 stations where they have the same equipment for which the system was made, obtaining more than favorable results in terms of load control in the workspace 1 (See Figure 11).

6. Conclusion

This study demonstrates the feasibility and efficiency of using an electronic control system to reduce energy consumption in industrial equipment, based on IoT technology for more optimal management and artificial intelligence for detecting objects or people, thus improving non-renewable resources such as electricity supply. The results and comparisons made show the reliability and feasibility of using the system for work in any industrial environment to be applied, in addition to performing proper management, maintenance scheduling and warning of failures to the supervisor and operator in a timely manner and prevent production from being affected.

It is concluded that the development and implementation of this system allow industrial production sectors to have optimal control in terms of energy savings through the use of equipment, improving production times, energy quality and better management in terms of results and KPI indexes, thus contributing to the sustainability and productivity of this sector.

Acknowledgments

We express our gratitude to the Universidad Nacional de San Agustín de Arequipa for its invaluable support and collaboration, which have been crucial to the success of this resea

References

[1] Paolo Visconti et al., "Machine Learning and IoT-Based Solutions in Industrial Applications for Smart Manufacturing: A Critical Review," *Future Internet*, vol. 16, no. 11, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[2] Yakub Kayode Saheed, Adekunle Isaac Omole, and Musa Odunayo Sabit, "GA-mADAM-IIoT: A New Lightweight Threats Detection in the Industrial IoT via Genetic Algorithm with Attention Mechanism and LSTM on Multivariate Time Series Sensor Data," *Sensor International*, vol. 6, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[3] Zhenyu Wu, Yanting Li, and Guangyao Zhang, “The Condition Monitoring Scheme for Industrial IoT Scenario: A Distributed Modeling for High-Dimensional Nonstationary Data,” *Computers and Industrial Engineering*, vol. 197, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[4] Dora Yvonne Arce Santillan et al., “Industrial Process Optimization through Advanced HMI Systems: Exploring the Integration of IoT and AI,” *Indonesian Journal of Electrical Engineering and Computer* Science, vol. 36, no. 2, pp. 817-825, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[5] S. Deepan et al., “AI-Powered Predictive Maintenance for Industrial IoT Systems,” *International Conference on Advances in Computing, Communication and Applied Informatics*, Chennai, India, pp. 1-6, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[6] Rachna Rana, Pankaj Bhambri, and Yogesh Chhabra, *Evolution and the Future of Industrial Engineering with the IoT and AI*, 1st ed., Integration of AI-Based Manufacturing and Industrial Engineering Systems with the Internet of Things, pp. 19-37, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[7] Xiangyu Lei et al., *Chapter 13: Digital Technology - AI-IoT in Transformation of Industrial Manufacturing*, Digital Transformation: Accelerating Organizational Intelligence Digital Strategies and Organizational Transformation, pp. 239-251, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Francisco Maciá-Pérez, Iren Lorenzo-Fonseca, and José-Vicente Berná-Martínez, “An AI-Based Ventilation KPI Using Embedded IoT Devices,” *IEEE Embedded Systems Letters*, vol. 16, no. 1, pp. 9-12, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[9] Krishanu Kundu, Manas Singh, and Aditya Kumar Singh, “Design and Development of IOT & AI Enabled Smart Entrance Monitoring Device,” *International Conference on Cybersecurity in Emerging Digital Era*, pp. 261-272, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Neeraj Gupta et al., “Economic Data Analytic AI Technique on IoT Edge Devices for Health Monitoring of Agriculture Machines,” *Applied Intelligence*, vol. 50, no. 11, pp. 3990-4016, 2020. [CrossRef] [Google Scholar] [Publisher Link]