

DEVELOPMENT OF AN INTELLIGENT MACHINE PARAMETERIZATION SYSTEM USING ARTIFICIAL INTELLIGENCE FOR INDUSTRY 4.0

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ABSTRACT

The development of intelligent machine parameterization systems represents a significant advancement in the context of Digital Transformation and Industry 4.0, promoting greater efficiency, productivity, and autonomy in industrial processes. In this scenario, the integration of Artificial Intelligence (AI), the Internet of Things (IoT), and automated systems enables the creation of solutions capable of monitoring, analyzing, and adjusting operational parameters in real time. The objective of this work is to develop an intelligent machine parameterization system using Artificial Intelligence techniques to optimize industrial processes, reduce operational failures, and improve decision-making in the manufacturing environment. For this purpose, an integrated system was implemented. The adopted methodology was based on the application of IoT sensors to collect operational data from machines, combined with machine learning algorithms for predictive analysis and automatic parameter adjustment through a collector installed in an integrated and automated manner. The system was structured within an integrated architecture, allowing real-time communication between equipment, databases, and an intelligent monitoring platform. The obtained results demonstrated an increase in operational efficiency, a reduction in machine setup time, a decrease in human errors, and an improvement in the quality of production processes. Furthermore, a greater capacity for machine adaptation to variable production conditions was observed. The conclusion highlights that the use of intelligent systems based on AI and IoT significantly contributes to industrial modernization, making processes more autonomous, efficient, and aligned with the principles of Industry 4.0, thereby strengthening competitiveness and technological innovation within organizations.



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I. INTRODUCTION

Digital transformation has promoted significant changes in industrial processes, driving the adoption of advanced technologies focused on automation, connectivity, and operational intelligence. In this context, Industry 4.0 emerges as a new production paradigm, characterized by the integration of cyber-physical systems, the Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, and real-time data analysis. These technologies enable greater efficiency, flexibility, and autonomy in industrial environments, contributing to increased competitiveness and technological innovation within organizations [1-3]. Among the main challenges faced by modern industry is the need to optimize machine parameterization, a fundamental process to ensure quality, productivity, and waste reduction in production. Inadequate parameterization can lead to operational failures, increased energy consumption, low production efficiency, and a higher incidence of human errors. In this scenario, the development of intelligent systems capable of automating and optimizing machine configuration becomes a strategic alternative for industrial modernization [4-7].

The development of an intelligent machine parameterization system using Artificial Intelligence represents an important contribution to the advancement of Industry 4.0. The application of intelligent algorithms makes it possible to analyze large volumes of data collected in real time by IoT sensors installed on industrial equipment, enabling the identification of operational patterns, prediction of failures, and automatic adjustment of machine parameters according to production conditions. This integration between AI and IoT promotes greater operational accuracy, reducing dependence on human intervention and increasing the reliability of production processes. Furthermore, the use of intelligent systems provides significant gains related to operational efficiency, cost reduction, product quality improvement, and increased machine availability. The connectivity provided by IoT enables continuous equipment monitoring, facilitating data-driven decision-making and supporting predictive maintenance strategies. In this way, organizations begin to operate in a smarter, more dynamic, and integrated manner, aligning themselves with the demands of digital transformation [8-11]. The relevance of this study is directly related to the growing need for industries to adopt innovative technological solutions capable of making production processes more efficient and sustainable. The proposal of an intelligent machine parameterization system contributes to strengthening industrial automation and to the evolution of traditional production models, promoting greater integration between humans, machines, and digital systems. Consequently, the innovation of this research lies in the development of a technological solution capable of combining Artificial Intelligence, IoT, and industrial automation within an integrated real-time environment, providing greater autonomy to machines and expanding the adaptability of industrial processes to market demands. Thus, the study reinforces the importance of digital transformation as an essential element for the advancement of Industry 4.0 and for the development of smarter, more connected, and more efficient industrial systems.

II. THEORETICAL REFERENCE

II.1 INTELLIGENT SYSTEM FOR MANUFACTURING

Intelligent systems applied to manufacturing have played a fundamental role in the modernization of industrial processes, especially in production environments that require high precision, speed, and quality, such as tape-cutting factories. With the advancement of Industry 4.0, companies have increasingly invested in technologies capable of automating processes, reducing waste, and increasing operational efficiency. In this context, intelligent systems emerge as innovative solutions that integrate Artificial Intelligence (AI), the Internet of Things (IoT), industrial sensors, and real-time data analysis to optimize machine operation and improve decision-making within the industrial environment [12-15]. In a tape-cutting factory, the production process requires a high level of control over parameters such as width, length, cutting speed, material tension, and spool alignment. Small errors in these parameters can result in raw material waste, failures in the final product quality, and increased operational costs. Therefore, the use of intelligent systems makes it possible to automate the parameterization of cutting machines, making processes more precise, safe, and efficient. The application of Artificial Intelligence in this industrial environment enables systems to learn from data collected during production. Sensors installed on the machines continuously monitor operational variables such as temperature, vibration, speed, and motor performance. This information is sent to intelligent platforms that analyze the data in real time, identifying patterns and automatically adjusting machine parameters whenever necessary. This process significantly reduces the need for manual intervention and minimizes operational errors [16], [17].

Another important aspect is the use of the Internet of Things (IoT), which promotes connectivity among equipment, systems, and operators. In a tape-cutting factory, IoT enables remote machine monitoring, facilitating production tracking and industrial operation management. In addition, connectivity allows the implementation of predictive maintenance strategies, in which failures can be identified before they occur, reducing unexpected downtime and increasing equipment availability [14], [18]. Intelligent systems also directly contribute to improving the quality of manufactured products. Precision in controlling cutting parameters ensures greater standardization of the produced tapes, reducing rework and waste. Furthermore, intelligent automation provides greater production flexibility, enabling rapid adjustments in machine settings according to different production demands. The implementation of these technologies represents an important advancement in the digital transformation process of industries. Companies that adopt intelligent systems can increase market competitiveness, reduce operational costs, and improve the efficiency of production processes. In addition, the use of solutions based on Artificial Intelligence and IoT supports industrial sustainability, as it reduces material waste, energy consumption, and operational failures [12-15]. Therefore, intelligent systems applied to manufacturing in tape-cutting factories represent an innovative solution aligned with the principles of Industry 4.0. The integration of automation, Artificial Intelligence, and industrial connectivity provides greater efficiency, quality, and reliability in production processes, contributing to the development of more modern, intelligent, and competitive industries.

II.2 MACHINE PARAMETERIZATION

Machine parameterization is a fundamental process in industrial automation and consists of configuring operational parameters required to ensure the proper functioning of equipment and production systems. These parameters may include speed, temperature, pressure, operating time, alignment, force, tension, among other factors that directly influence the efficiency, quality, and safety of industrial processes. Proper parameterization allows machines to operate in an optimized manner, reducing failures, waste, and operational costs. One of the main characteristics of machine parameterization is the ability to adapt equipment operation according to the specific needs of each production process. In modern industrial environments, different products require distinct configurations, making machine flexibility essential to meet production variations. In this way, parameterization enables fast and accurate adjustments, contributing to higher productivity and reduced setup time [19-21]. Another important characteristic is the automation of operational parameters through intelligent systems. With the advancement of Industry 4.0, technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and intelligent sensors have been integrated into industrial systems, allowing machines to perform automatic real-time adjustments. These systems continuously monitor equipment performance, collecting operational data and identifying patterns that support decision-making and the optimization of production processes [22-25]. Precision is also an essential characteristic of machine parameterization. Small errors in parameters can compromise the final quality of products, resulting in raw material waste, rework, and financial losses.

Therefore, modern systems use control and monitoring software capable of ensuring high reliability in operational configurations, significantly reducing the occurrence of human errors. The applications of machine parameterization are broad and present across various industrial sectors. In the manufacturing industry, for example, parameterization is used in cutting, machining, welding, and automated assembly machines. In the food industry, parameters control temperature, cooking time, and production speed. In the textile industry, parameterization ensures precision in cutting, sewing, and finishing processes [19], [24-26]. In addition, parameterization is widely applied in robotic systems and automated production lines, where different equipment must operate synchronously and efficiently. Integration with intelligent systems enables greater control of industrial processes, supporting predictive maintenance, reducing energy consumption, and promoting continuous production improvement. Therefore, machine parameterization represents a strategic element for industrial modernization, contributing to more efficient and safer processes aligned with the principles of digital transformation and Industry 4.0.

II.3 DIGITAL TRANSFORMATION AND INDUSTRY 4.0

Digital Transformation and Industry 4.0 represent one of the greatest technological and organizational changes of the modern era, promoting the integration of digital technologies, automation, and computational intelligence into the production and administrative processes of companies. These changes have impacted various sectors of the economy, especially industry, making processes more efficient, connected, and intelligent. Digital Transformation is related to the strategic use of digital technologies to improve operations, products, services, and business models, while Industry 4.0 corresponds to the application of these technologies within the industrial environment. One of the main characteristics of Digital Transformation is the digitalization of processes, enabling information to be collected, stored, and analyzed in real time. Technologies such as cloud computing, Big Data, Artificial Intelligence (AI), the Internet of Things (IoT), and industrial automation are widely used to increase operational efficiency and improve decision-making. Furthermore, connectivity among systems and equipment allows greater integration between sectors, promoting agility and cost reduction [27-29]. Industry 4.0, also known as the fourth industrial revolution, is mainly characterized by the integration between physical and digital systems through cyber-physical systems. In this industrial model, machines, sensors, and software operate in a connected and intelligent manner, enabling continuous monitoring of production processes. Another important characteristic is advanced automation, in which machines can make automatic decisions based on data collected in real time.

Production flexibility also stands out in Industry 4.0. Smart factories can quickly adapt their production lines to market demands, increasing product customization and reducing waste. In addition, predictive maintenance is a relevant application, enabling the identification of possible failures before they occur, reducing unexpected downtime and increasing equipment availability. The applications of Digital Transformation and Industry 4.0 are present in several industrial sectors. In manufacturing, for example, they are used in automated production systems, industrial robotics, intelligent machine control, and remote process monitoring. In logistics, digital technologies enable real-time product tracking and optimization of transportation and storage. In the energy sector, intelligent sensors assist in consumption control and energy efficiency. These technologies contribute to improving product quality, reducing operational costs, and increasing business competitiveness. The integration of Artificial Intelligence, IoT, and automation promotes smarter, safer, and more sustainable industrial environments [27], [29-31]. Therefore, Digital Transformation and Industry 4.0 represent a significant advancement in industrial modernization, promoting innovation, connectivity, and efficiency in production processes. These technologies make organizations better prepared to face the challenges of the global market and drive the development of smart and highly automated factories.

III. MATERIALS AND METHODS

The method employed in this work was based on an applied, incremental, and multidisciplinary approach for the development of an industrial IoT architecture aimed at monitoring operational variables in smart manufacturing environments aligned with the principles of Industry 4.0. The development process was structured into integrated stages involving requirements gathering, system architecture modeling, embedded hardware development, firmware implementation, communication infrastructure, data persistence, and experimental validation in a real industrial environment. Initially, requirements engineering and analysis of the industrial environment were conducted, involving the mapping of production processes, identification of the monitored machines, and definition of the operational variables relevant to the data acquisition system. At this stage, aspects related to electrical infrastructure, electromagnetic conditions of the environment, instrumentation points, connectivity requirements, and operational constraints of the industrial process were evaluated. In parallel, the production flow was modeled, enabling the definition of the functional architecture of the IoT solution, as well as the integration requirements among the hardware modules, firmware, and computational backend.

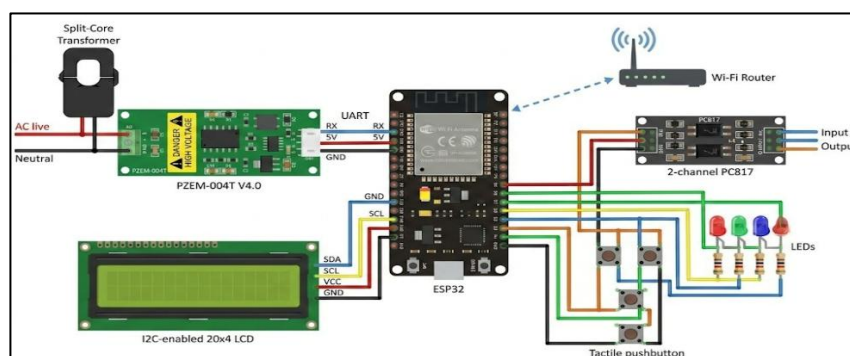


Figure 1: Collector Architecture.

Source: Authors, (2026).

At the hardware layer, an embedded IoT collector was designed and developed for the continuous acquisition of electrical quantities and production variables from industrial machines. The electronic architecture of the prototype incorporated power supply subsystems, analog signal conditioning, electrical isolation, protection against surges and electromagnetic interference, as well as serial communication interfaces and voltage and electric current sensing modules. The electronic design was conceived considering industrial robustness criteria, electromagnetic compatibility, operational reliability, and scalability for future industrialized versions of the device. The embedded firmware was developed in the C programming language due to its high computational efficiency, low memory overhead, and compatibility with real-time applications in microcontroller-based systems. Dedicated routines were implemented for analog signal acquisition, digital filtering, metrological calibration, local processing of monitored variables, and periodic data transmission to the central server. Additionally, communication management mechanisms, fault handling, and automatic network reconnection features were incorporated in order to increase the operational reliability of the IoT system in industrial environments. In the computational infrastructure, a backend architecture based on Node.js was implemented using a service-oriented model and asynchronous communication for receiving, processing, and managing data from the embedded collectors. This approach enabled high scalability, modularity, and efficiency in handling continuous industrial telemetry streams in near real time.

For data persistence, the PostgreSQL database management system was used, selected due to its transactional robustness, referential integrity, and high capacity for storing and processing large volumes of industrial data. The database modeling was structured in a normalized manner, enabling historical traceability, information consistency, and support for the future application of analytical techniques and industrial data mining. Additionally, a provisioning and device-enablement interface for IoT devices within the industrial network infrastructure was developed, allowing secure authentication, Wi-Fi connectivity configuration, operational parameterization, and remote management of the collectors. This functionality significantly contributed to reducing the complexity of installation, maintenance, and lifecycle management of field devices. Finally, the experimental validation of the solution was conducted through the deployment of IoT collectors on real industrial machines, enabling the evaluation of communication stability, integrity of transmitted data, embedded system performance, and operational robustness under adverse factory environment conditions, including electrical noise and electromagnetic interference typical of industrial applications.

IV. RESULTS AND DISCUSSIONS

The experimental results obtained demonstrated the technical and operational feasibility of the proposed IoT architecture for industrial monitoring applications in smart manufacturing environments. The developed solution showed a high integration capability among the embedded hardware subsystems, communication infrastructure, and data persistence layer, enabling continuous acquisition, distributed processing, and reliable real-time transmission of the monitored variables. The implementation of the database architecture constituted a fundamental stage for the consolidation of the platform, being responsible for the storage, organization, and management of telemetry information from the IoT collectors installed on the monitored machines. The structure was designed to support the continuous recording of electrical and operational variables, including voltage, current, operational status of the devices, connectivity parameters, collector identification, and temporal information related to data acquisition. The relational modeling was developed using the PostgreSQL database management system, adopting principles of normalization, referential integrity, and transactional consistency. This approach enabled the construction of a robust and scalable architecture capable of ensuring temporal traceability, storage reliability, and efficient management of the large volume of data continuously generated by the embedded devices distributed throughout the industrial environment.

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2	2417	352000	Ativo	2026-01-13	17:48:00	220.5	3.18	12345678	192.168.101.38
3	3587	352000	Ativo	2026-01-14	10:16:24	220.5	3.18	12345678	192.168.101.38
4	3593	352000	Ativo	2026-01-14	10:16:22	220.5	3.18	G123689s	192.168.101.54

Figura 2: Table.
Source: Authors, (2026).

Figure 2 presents the structure of the main telemetry data storage table used in the developed platform. The organization of the attributes responsible for identifying the collector devices, storing the monitored electrical variables, communication parameters, and temporal records of the performed measurements can be observed. The adopted structural standardization favored the integration between the data acquisition layer and the application backend, in addition to optimizing query processes, historical analysis, and analytical processing of operational information. The implemented computational architecture presented satisfactory performance regarding the persistence and retrieval of industrial telemetry data, maintaining information integrity even under simultaneous operation of multiple IoT devices. The conducted tests demonstrated stability in communication between the embedded modules and the backend infrastructure, showing low latency, reliability in data packet transmission, and automatic reconnection capability under typical industrial operating conditions. The proposed structure was designed with a focus on interoperability and future platform expansion, enabling integration with supervisory systems, predictive analysis tools, applications based on Artificial Intelligence, and advanced data mining techniques. In this way, the developed solution establishes a consistent technological foundation for applications aligned with the paradigms of Industry 4.0, contributing to the advancement of intelligent architectures aimed at industrial monitoring and the digital transformation of manufacturing environments. The communication tests between the embedded collectors and the backend infrastructure confirmed stability and reliability in the transmission of operational data. The system demonstrated robust behavior under typical industrial operating conditions, maintaining low communication latency, automatic reconnection capability, and integrity of transmitted packets, which are essential factors for continuous industrial IoT monitoring applications.



Figure 3: Voltage and Current Sensor Reading Circuit.
Source: Authors, (2026).

From an electromechanical and electronic perspective, the integration of voltage and current sensors into the embedded system enabled continuous monitoring of the electrical quantities associated with industrial machines, allowing accurate acquisition of parameters related to energy consumption and the operational status of the equipment.

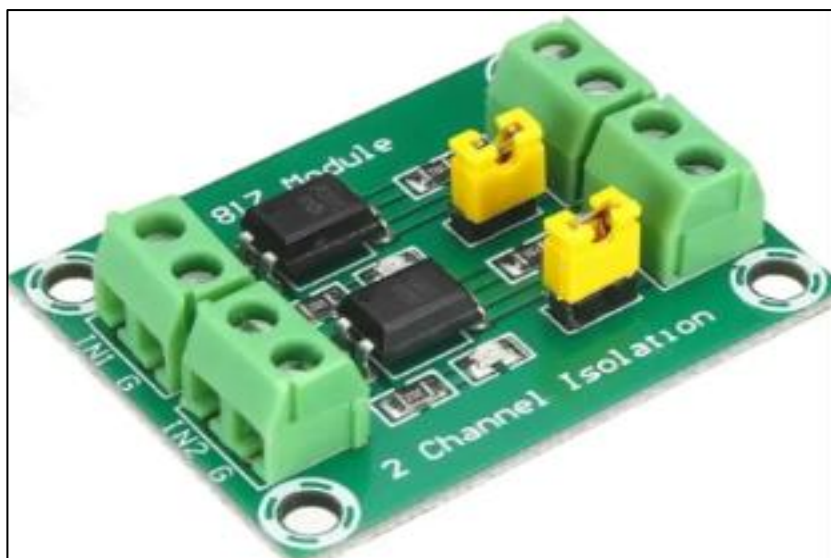


Figure 4: 2-Channel Optocoupler Module.
Source: Authors, (2026).

The 2-channel optocoupler module was implemented with production counting mechanisms based on inductive and infrared sensors, enabling correlation between electrical variables and productive indicators of the industrial process. During the validation phase in a real industrial environment, electromagnetic interference associated with the operation of industrial pneumatic devices, especially solenoid valves, was identified, causing degradation in the integrity of the digital signals used for production counting. The technical analysis indicated that the conducted and radiated noise present in the industrial electrical infrastructure generated spurious pulses in the input circuits of the embedded system, compromising the reliability of signal acquisition from the sensors.

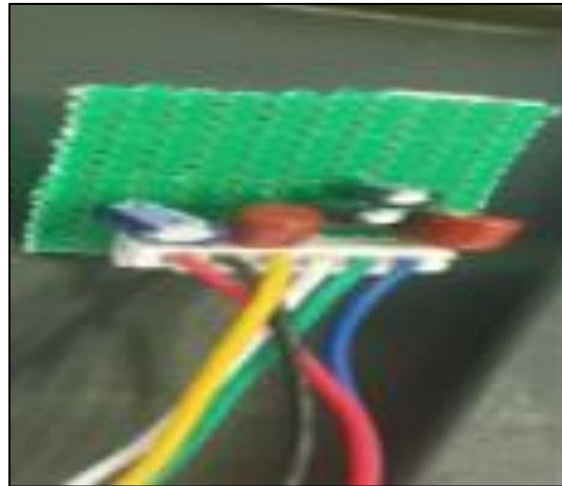


Figure 5: Capacitive Filter.

Source: Authors, (2026).

The experimental analysis of the system showed that industrial environments characterized by the presence of inductive loads, power drives, frequency inverters, electric motors, and electronic switching devices represent a significant source of electromagnetic interference capable of compromising the performance of the embedded modules responsible for the acquisition and transmission of telemetry data. During the operational tests carried out on the developed IoT architecture, it was observed that electrical noise propagated both through the power supply network and communication lines directly affected the stability of the measurements and the reliability of the real-time data acquisition process. The identified interferences presented different spectral and behavioral characteristics, including high-frequency noise, switching transients, electromagnetic surges, and oscillations resulting from the simultaneous activation of industrial loads. Such phenomena may cause distortions in the analog signals acquired by the sensors, instabilities in the logical levels of digital inputs, and intermittent failures in communication between the embedded devices and the backend infrastructure. In connected industrial systems, these occurrences represent a critical factor, since they can compromise the integrity of the collected information and reduce the operational reliability of the monitoring platform. In view of this scenario, mitigation strategies aimed at electrical conditioning and filtering of the signals acquired by the embedded modules were proposed and implemented. The adopted techniques had the main objective of increasing the electromagnetic immunity of the IoT architecture, reducing the susceptibility of the circuits to external interference, and ensuring greater stability in the acquisition, processing, and transmission of the monitored variables.

Among the approaches employed, the implementation of capacitive filters in the power supply circuits and analog acquisition interfaces stands out. The use of decoupling and filtering capacitors made it possible to reduce voltage oscillations, minimize high-frequency noise, and stabilize the power supply to the microcontrollers and sensors connected to the system. These elements play a fundamental role in suppressing electromagnetic disturbances conducted through the electrical network, acting as barriers against undesirable high-frequency components that could compromise the proper functioning of electronic devices. In addition to capacitive filters, improvements were applied to the decoupling circuits distributed throughout the electronic architecture of the IoT collectors. Proper decoupling among electronic components contributed to reducing the unwanted coupling of noise between different circuit stages, especially among the processing, communication, and analog acquisition modules. The adoption of ceramic capacitors positioned close to the power supply terminals of the integrated circuits reduced instantaneous voltage variations and improved the electrical stability of the system during transient operating conditions. Another relevant aspect considered during the mitigation process was the adequacy of the electrical grounding infrastructure of the embedded devices and sensors connected to the platform. In industrial environments, grounding failures or potential differences between equipment may favor the circulation of parasitic currents and the emergence of electromagnetic interference capable of significantly degrading the quality of the acquired signals. Therefore, practices aimed at standardizing functional and protective grounding were adopted in order to minimize ground loops, reduce induced noise, and ensure greater electromagnetic stability for the system.

The physical reorganization of the power and communication cables also constituted an important measure to reduce the effects of electromagnetic interference. The separation between power cables and low-voltage signal lines contributed to reducing inductive and capacitive electromagnetic coupling between adjacent conductors. Additionally, routing and shielding criteria were employed to minimize the incidence of noise on the data acquisition channels and serial communication interfaces used in the IoT architecture. In the context of digital inputs, optimizations were carried out on the acquisition interfaces with the objective of increasing the system immunity against electrical oscillations and false switching caused by industrial noise. The implementation of the ESP32 internal pull-up resistors associated with logic filtering and software timing techniques made it possible to reduce occurrences of incorrect reading of digital signals from sensors and external devices. These strategies contributed to increasing the reliability of the acquisition process and avoiding incorrect interpretations of the operational status of the monitored machines.

Additionally, electrical isolation techniques applied to the critical interfaces of the system were analyzed, especially in channels subject to higher levels of electromagnetic interference. The use of optocouplers and galvanic isolation circuits represents an efficient approach to reducing noise propagation between different subsystems of the embedded architecture, as well as increasing the protection of electronic devices against surges and potential differences present in industrial environments. The results obtained after the implementation of the mitigation strategies demonstrated significant improvements in the operational stability of the IoT platform. A reduction in the occurrence of inconsistent readings, greater reliability in the acquisition of monitored electrical variables, and increased robustness of communication between the embedded modules and the application backend were observed. The platform presented more stable behavior even under industrial conditions characterized by high electromagnetic activity, demonstrating the effectiveness of the adopted conditioning and filtering techniques. From a metrological perspective, the implemented improvements contributed to increasing the accuracy and repeatability of the measurements performed by the sensors connected to the system.

The reduction in electrical noise levels enabled greater integrity of the acquired signals, favoring the reliability of operational analyses and the information stored in the platform database. This aspect is particularly relevant in continuous industrial monitoring applications, in which small distortions in signals can directly impact supervision processes, decision-making, and predictive maintenance. In addition to the immediate benefits observed in the operational stability of the developed solution, the implemented mitigation strategies establish an important foundation for future expansions of the IoT architecture in industrial environments with greater electromagnetic complexity. The adoption of appropriate electromagnetic compatibility, filtering, and signal conditioning practices becomes essential to ensure scalability, reliability, and interoperability in connected systems aligned with the concepts of Industry 4.0 and smart manufacturing. Thus, it can be concluded that the implementation of signal conditioning and filtering techniques played a fundamental role in improving the operational robustness of the proposed IoT platform. The adopted solutions made it possible to significantly increase the electromagnetic immunity of the system, reduce susceptibility to external interference, and ensure greater reliability in the acquisition and transmission of industrial data, contributing to the development of a more stable, secure, and suitable technological architecture for the demands of modern industrial environments.



Figure 6: Collector Installed on the Machine.

Source: Authors, (2026).

The obtained results demonstrate that the developed architecture presents high potential for application in scenarios associated with Industry 4.0, especially in solutions for remote monitoring, industrial telemetry, energy supervision, and distributed industrial data acquisition. Furthermore, the modularity of the conceived architecture enables future expansions involving predictive maintenance techniques, intelligent data analysis, integration with cyber-physical systems, and the application of machine learning algorithms aimed at optimizing industrial production processes.

V. CONCLUSIONS

The Voltage and Current Sensor Reading Circuit showed stable performance in the acquisition of electrical parameters, ensuring measurement accuracy and appropriate conversion of analog signals for digital processing. The results indicated good sensitivity and fast response to the operational variations of the monitored machine. The 2-Channel Optocoupler Module played a fundamental role in the electrical isolation between the power and control circuits, providing greater system safety and reducing electromagnetic interference. This characteristic significantly contributed to the stability of the readings and the protection of electronic components. The Capacitive Filter applied to the circuit enabled the reduction of noise and undesirable oscillations in the electrical signals, improving the quality of the collected information and increasing the reliability of real-time monitoring. In summary, the Collectors installed on the machines confirmed the practical feasibility of the proposed solution, operating continuously and efficiently under real operating conditions. The obtained results demonstrate that the developed system has strong potential for applications in predictive maintenance, industrial automation, and intelligent equipment monitoring on the factory floor.

VI. AUTHOR'S CONTRIBUTION

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Approval of the final text: Jandecy Cabral Leite, Marcelo Maia do Nascimento, Anderson Alexandre Silva de Almeida, Matheus Pereira de Souza, Leonardo da Silva Martins, Paulo Ricardo Ferreira da Silva and Marcos Henrique Gomes Brasil.

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