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INTEGRATION OF PROGRAMMABLE LOGIC CONTROLLER WITH DATABASE AND WEB APPLICATION IN THE WOOD PROCESSING INDUSTRY.

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Abstract. *The demand for acceleration of complex production processes requires new approaches to production, where integrated and efficient systems are essential. Nowadays, there is a significant growth in the applications of the concept of Industry 4.0 in Brazil and in several other countries to increase efficiency and competitiveness in industry. In this paper, the development of a monitored system in a wood processing company is presented. The purpose of this project is to show the operation of machines and processes in the extraction plant in real time and provide data for management systems. The main contribution of this work is the application of integration techniques and the development of codes based on the study of practical cases applied to an existing industrial environment. Data communication technologies over an Ethernet network, Schneider Programmable Logic Controller (PLC), programming and simulation software, an Structured Query Language (SQL) database, and a web application in the Laravel, Hypertext Preprocessor (PHP) framework are used to develop and integrate this system.*

Keywords: *PLC, Industry 4.0, System Control.*

1. INTRODUCTION

Companies around the world are increasingly using robots and automation processes. According to IFR (International Federation of Robotics), the use of robots in industry has only increased over the past decade. The integration of computing resources, robotics and automation has significantly improved the quality, price and performance of production processes in recent years, Atkinson (2019). Since automation and computing are potentially innovative general-purpose technologies, the key question is how this will affect production processes and global marketing sectors such as manufacturing. The last major wave of technology, driven by information technology, was largely decentralized and enabled the geographic distribution of supply chains to the periphery. The next wave of technology innovation based on robotics and automation will have the opposite effect, enabling a realignment of manufacturing to the core. We need to look to the prospects of automation and computing and consider their impact on social and technological dynamics. Although there is disagreement in the scientific community about the relative contribution of factors such as globalization, deregulation of industry, laws, etc., it has been proven that automation is one of the main factors in technological and social development, Berger and Engzell (2022).

According to Isak and Predrag (2022), over the past decade, the development and implementation of robotics and digital technology has taken us from the third industrial revolution to the fourth industrial revolution. As part of its development strategy, Germany introduced digital technologies in production processes in 2011 under the name “Industry 4.0” ." The German example is followed by the following countries: United states of america (USA), United Kingdom (UK), Sweden, Japan and others. Almost all technologically developed countries are striving to introduce advanced technologies in production processes in order to maintain their competitive position on the market. The implementation of the fourth technological revolution depends on a number of innovative technological achievements. It is necessary to integrate production processes at all stages of product development and monitor the useful life of products through the use of advanced technologies. On the other hand, systems for controlling industrial processes draw attention to problems of manageability and safety, Cruz *et al.* (2016).

Alternatively, increasing developments in the automation and manufacturing industries have created a demand for PLC training Sang *et al.* (2011) automation systems. Since the inception of PLCs for industrial automation and control, technicians, engineers, and students have faced the challenge of understanding the operation and functioning of systems controlled by a PLC. Due to the high cost associated with programmable logic controller courses and training, as well as the demand for constant change in the industry, companies and institutions have struggled to find the training necessary to use PLC. Nowadays, the automation and robotization of various industrial processes, which was considered a trend, has become more and more a reality. This is the case of companies in the wood sector, which require a lot of work in different types of services. In these industries, for example, we have the final product: MDF, furniture, doors and flooring. Automation is a great ally in ensuring production levels in terms of price, quality and durability. Another important point is that companies are increasingly investing in process control technologies, combining machine and production data, creating sophisticated reports for decision making, and developing modern production environments with autonomous machines and high availability. Production, automation and process issues also include maintenance, an area that is responsible for the availability and functioning of an entire production park. Good maintenance management ensures that the industry is in control of production costs and the quality of the final product by predicting failures and making improvements. In companies engaged in processing raw wood into various products, one often finds machines with very similar purposes. Regardless of the size of the company, a common and indispensable element in these industries is an exhaust system capable of removing dust and residues generated during woodworking. The exhaust system consists of a series of motors, filters, valves and pipes arranged in a cascade. They act as air vacuums that remove the accumulation of particles from the machines, and the failure or lack of an exhaust mechanism makes the use of machines and processes impracticable.

2. Basic Concepts

Nowadays, the term automation is widely used in factories and industry. Mass production of various products, no matter in which segment, required more modern and efficient means of production. Automation of services enabled industry to produce larger quantities of products with a smaller amount of labor and manual services. Computerization also enabled the creation of various technical occupations. Some studies associate the beginning of automation with the IT revolution that brought computers into everyday life. The term automation was created and spread by industrial marketing starting in the 1960s. The idea was to demonstrate the integration of computers into industrial process control, de Moraes and de Lauro Castrucci (2010). The goal of companies in implementing automated processes goes beyond the desire to increase productivity and reduce costs. Automating and managing processes requires skilled labor, specific tools and equipment that meet the standards of the processes being used. Industries that adopt automated processes seek to manage and control their products with greater precision, increase quality, and become competitive organizations within the segment in which they operate.

The concept of automation refers to the idea of controlling and using electrical or mechanical energy to move some type of machine. The purpose of automation is to provide intelligent instructions to the machine so that it performs its task correctly and safely within its design limitations. From this perspective, automation and control are like ingredients in an industrial process that give machines intelligence. According to de Moraes and de Lauro Castrucci (2010), the advantages of implementing computerized systems in industrial de Moraes and de Lauro Castrucci (2010): the possibility of integration, expansion and better control of the maintenance of the components involved. Looking at an automated plant, one finds several interconnected interfaces: PC, PLC, HMI, sensors, pneumatic actuators, signal and power cables, and various electromechanical components. The computerization of an industry means the centralization of the information obtained in the productive areas through components for the management areas. To understand how the operation of automated systems in industry works in practice, it is necessary to consider their hierarchical architecture. Following de Moraes and de Lauro Castrucci (2010), we can represent the hierarchy by the automation pyramid. At the base of the pyramid are physical devices, PLCs and the like, which receive the field signal and then act on the other electromechanical controls. In the middle are monitoring technologies that serve as a bridge between the base and the top and IHM operate at this point. At the top of the pyramid are concentrated the process and production information associated with management and control.

3. Planning and Implementation

This section presents the project developed to build a monitoring system for industrial automation integrated with a database and a web application. The project architecture is based on the plan of a real company that manufactures wooden doors, taking into account the structure of the components and machines that make up the extraction system in this industry.

Thesystem Gls industrial fan consists mechanically of: Pipes, rotary valves, suction motors, dust filters. Electrically it consists of: Gls sensors, Gls contactors, Gls relays, Gls electronic starters and control PLC. All of these components are physically connected to each other and are used to dispose of the raw material produced during woodworking in a central silo, where the material is burned or extracted. In order to understand the operation of the exhaust fan system, it is necessary for all components to work together logically, as the process of extracting dusts from woodworking and conveying them to the main silo depends on the cascading operation of the actuation mechanisms of the process. Figure 1 below shows a series of wood dust extractors.

In practice, for the system to start operating in automatic mode, at least one machine connected to an exhaust fan must be turned on. This process called start will execute several calls in cycles until it starts pulling in air with waste. On a day-to-day basis, during the start process that will begin the operations cycle of the PLC or interlocking relays, anomalies may appear that cause the exhaust fan system to not work, various problems may occur such as: disarming a protection system, clogging of raw material transport piping, fires or failure of mechanical and electrical systems in the field. At this

Figure 1. Industrial dust extractors.
Source: Brandt (2022)

point, it is necessary to integrate the information managed by PLC with a supervisory system, which shows the situation from an operational point of view. In addition to an operational-level supervisory system, implement a system capable of storing device information and creating a history of events to speed up the production and maintenance process as a whole.

A monitoring system can encompass multiple technologies, so combined mechanisms have been used to allow the application to be extended to other areas of the enterprise. Based on this premise, the main collaborative technologies were selected for simple learning that have the flexibility to design a complex application, depending on the industrial process applied. As in this case study, the combination of the technology in the factory floor with a web application in flexible language allows the preparation of a monitoring system with different information and data that can be used in the future at strategic and management levels. For the design and subsequent development of an automation system integrated with a database and a web application, it was necessary to describe and divide the main requirements that affect the structure of the application. For this purpose, a table with the most important comprehensive requirements for each phase of the project was created. Following the software requirements, a field study of the project was carried out in order to collect all the components and devices that are relevant and integrated in a certain way with the PLCs. With this data, it is possible to measure the number of contactors, relays, valves and motors that make up the system, which served as the basis for modeling the ladder logic algorithm, the DB and later the web application. In practice, these components are distributed across several control panels throughout the factory in a square area of about $90,000m^2$.

In the second phase of the field study, all digital inputs and their functions were listed in the PLC. Digital inputs indicate the status of physical devices. Then, the inputs were used as guidance parameters in the data acquisition and control algorithms. The Gls Ladder algorithm was developed in the EcoStruxure Machine Expert environment, a software for developing and programming PLC tailors. The TM200CE40U controller model, firmware version 1.12.2.0, with the TM2DDI32DK and TM2DDO16TK expansion modules was used for the case study. Within the software, POU were created to stage the entire cascade process responsible for interlocking the physical components. Ladder diagrams abstract algorithms in the form of functional blocks and simplify configuration and control logic. Within the development environment, it is possible to simulate the physical control and test each control module. The TM200CE40U controller model has 24 digital inputs and 16 digital outputs, the TM2DDI32DK expansion module has 32 additional digital inputs, and the TM2DDO16TK module has 16 additional digital outputs. This configuration makes it possible to simulate an application with a total of 88 digital inputs and 48 digital outputs. The choice of this device model is due to the fact that it already has an Ethernet communication interface through the ModBus/TPC protocol via an RJ-45 network connector. Later, in the Programming tab, functions were created in the form of a ladder diagram algorithm that takes into account the cascade sequence for controlling the exhaust system. In the Programming tab, each POU represents a part of the cascade process that connects the machines to their respective transports and the main line. In the Commissioning tab, the miniature control can be generated and the inputs and outputs can be tested, with the simulation mechanism being identical to that of the physical control. The IHM control interface IHMwas developed in the Vijeo Designer 6.2 environment, a software for developing and programming Schneider exclusive interfaces. The XBTGT7000 series simulation device, model XBTGT7340 (1024x768), was selected for this case study. PhpMyAdmin was chosen as the database manager for storing the generated data, and the database is run through the XAMPP application, which includes a server for SQL and PHP statements. The XAMPP version installed and used was V3.3.0. Figure 2 shows the manager that allows you to configure, enable and disable the MySQL database.

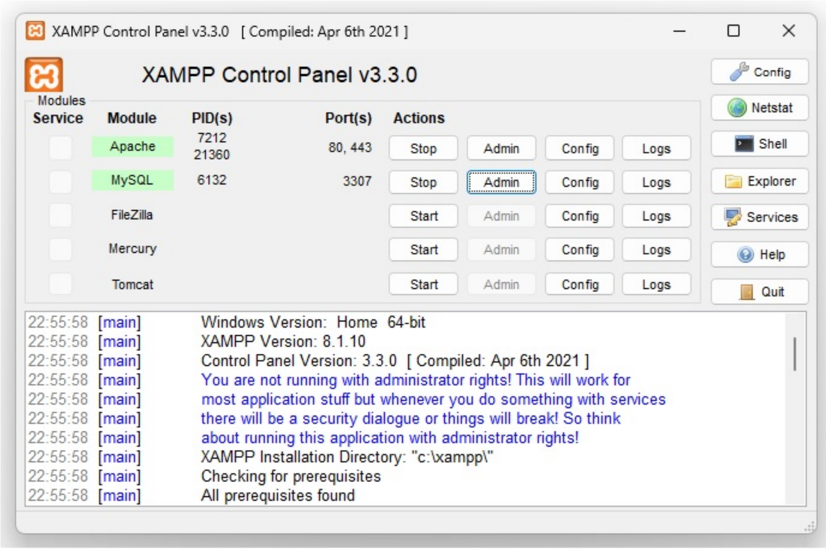

Figure 2. XAMPP Control Panel.
Source: Autor.

PhpMyAdmin was chosen as the database manager for storing the generated data, and the database is run through the XAMPP application, which includes a server for SQL and PHP statements. The XAMPP version installed and used was V3.3.0, and the figure below shows the manager that allows you to configure, enable and disable the MySQL database. The web application was the most complex part of the project. In order to create the application, it was necessary to prepare the development environment. In this case, some software and resources were used, such as Visual Studio Code, GitHub and Laravel PHP Framework. The Laravel algorithm interacts with the database previously created in PhpMyAdmin via SQL statements.

Using the Laravel framework allows you to turn comprehensive notations and requirements into algorithms and lines of code, using a range of languages such as: PHP, HTML, SQL. Combining these languages with Laravel's structure and functionality facilitates code learning, development and maintenance through MVC structures. Visual Studio Code version 1.73.0 was chosen as the software for processing the algorithms. VSCode as shown in figure 3, as it is called, allows you to integrate multiple extensions from the most diverse software used by developers to facilitate the creation and maintenance of codes.

For the development of the web system, the programming environment was first prepared using GitHub as the version control tool, where each part of the software is executed, tested and added to the whole using the git, commit, pull and push commands. The TCC-2022 repository was created within the GitHub account. Later, Visual Studio Code's code editor was used to link the local repository to the remote GitHub repository. The controllers created for each model contain the code functions responsible for processing the associated data and connecting the View, Model, and Database layers. In practice, each function was coded to insert, modify, delete, and list information and the associated models, as well as determine what information is made available in the views. The PHP class coded below illustrates the organization of functions into controllers.

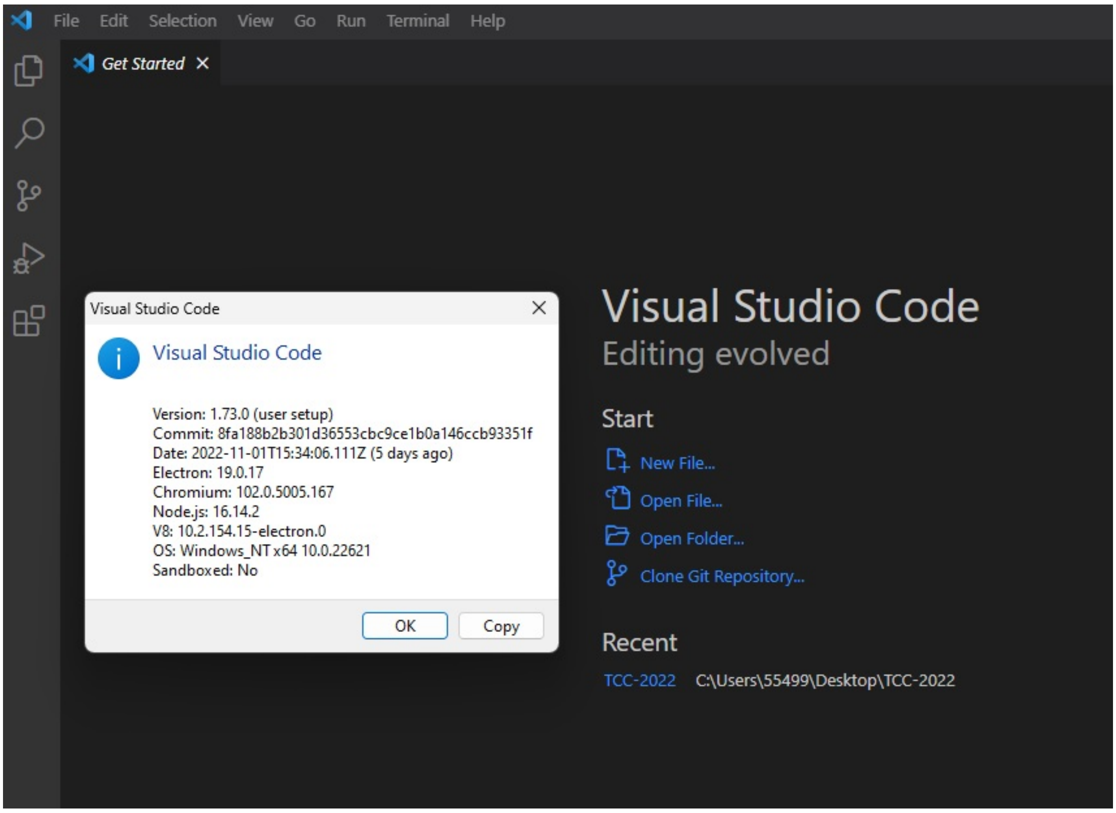

Figure 3. Visual Studio Code.
Source: Autor.

4. Results

At the end of the research and development study of this project, it was possible to develop, simulate and test an industrial automation application to manage an exhaust fan system through a PLC and a Schneider HMI in conjunction with a web application developed in the Laravel PHP framework. By integrating these technologies, it was possible to remotely simulate the operation of the exhaust fan system through the HMI, as well as access notifications of events related to the process captured by the PLC; the data is visible through a responsive web application. Registration and management functionalities could be implemented in the web application: Users, PLC machines and events that return data in the form of tables and charts.

The present work has achieved the proposed goals, as it enables the execution of tests that return information from the physical reality of machines to a data management system via a web application. Thus, the web application also assumes the role of a monitoring system, since it allows the listing and processing of active events. The first specific goal of the control process simulation can be seen in Figure 4, where the physical device and ladder logic algorithm are shown. When an input is activated by a user command, the corresponding memory becomes active (highlighted in green).

The second specific objective in modeling a database can be seen in Figure 5, where the database is shown: "tcc" with its respective tables and user records registered through the web application. The third specific objective in developing a web application , where the screens are shown for users to register and view the system resources. , it is possible to check the navigation menu listing the active alarms as we can see in figure 6. The fifth specific objective of transforming data into management information , where the screens are shown for users to list the registered items, it is possible to check, for example, a graph generated with information from a machine:

The development of system prototypes and their simulations will enable the automatic capture of information and data between machines and systems. Automatic fault recording will eliminate the need for manual recording, as events will be automatically recorded in the alarm tables. Based on the data stored in the database, users, administrators, operators and system supervisors can make decisions based on real-time information about the process as we can see in figure 7.

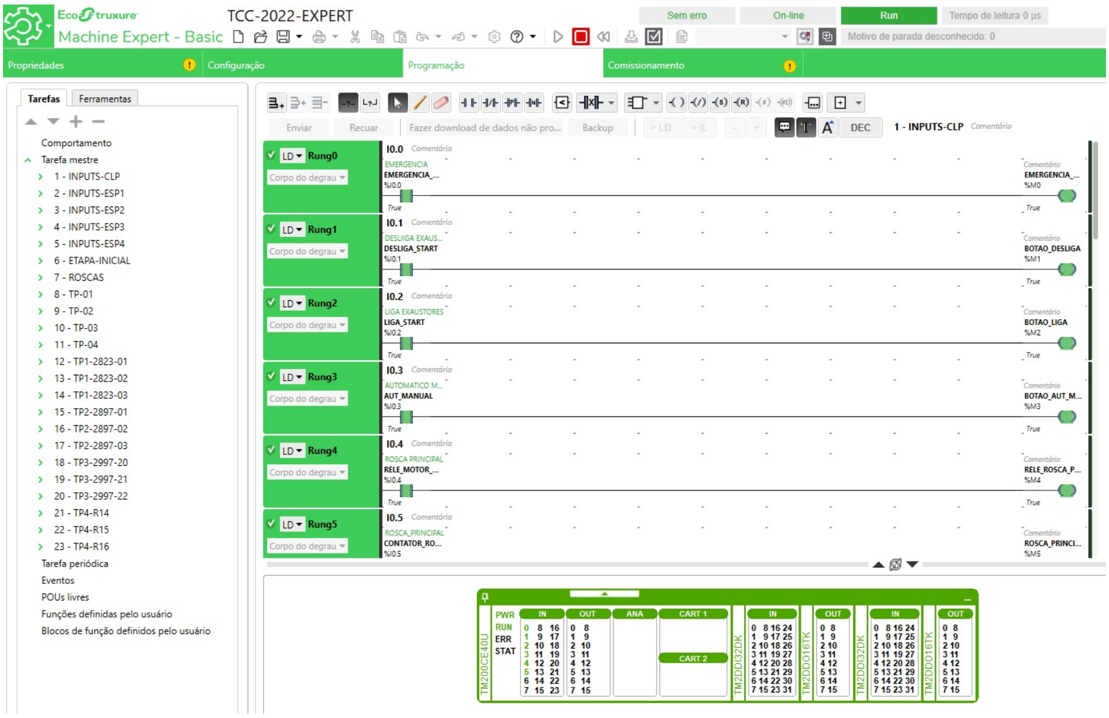

Figure 4. Control process simulation in Ladder language.
Source: Autor.

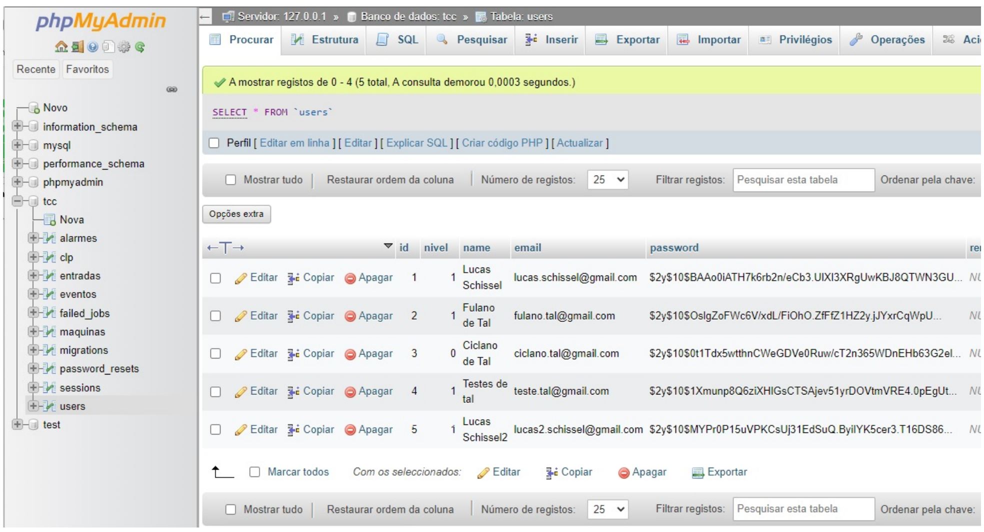

Figure 5. "tcc" Database
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Figure 6. List of active alarms.
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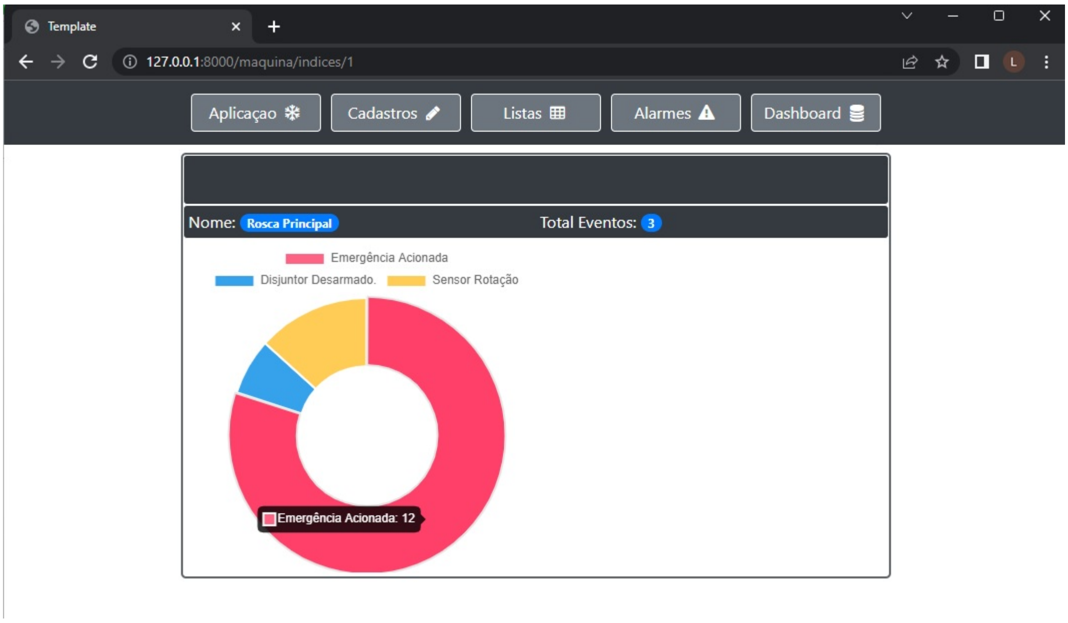

Figure 7. Management chart
FONTE: Autor.

5. Conclusions

This work started with a case study and a problem related to an exhaust fan system in a wood processing industry. Based on this problem, studies and research were carried out that included the field of automation, monitoring systems, databases and web applications. With this approach, it was possible to relate some of the main technologies used in the research context to the reality of the company. In this way, the requirements were collected and a project was developed to model, implement and develop software that integrates an industrial automation system with computer systems, using the methods, techniques, knowledge and learning studied in Computer Science and taught in the Information Systems course. To conclude this work, we can highlight the great impact that the data collected and managed in the web application can have on the organization when the mentioned technologies and resources are implemented. It is expected that the resources developed in this work can be improved and extended to other machines and devices, regardless of brand or manufacturer.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE