Journal of Technical Invention 8[21]1-7: e20821107
Article

Implementation of a system ANDON for the utilities department in a plastic injection plant

Desarrollo de un sistema ANDON para el área de servicios en planta de inyección de plástico

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CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: Electronic Engineering
Subdiscipline: Automation and Control

https://doi.org/10.35429/JOTI.2024.8.21.1.7

Article History:
Received: January 23, 2024
Accepted: December 31, 2024

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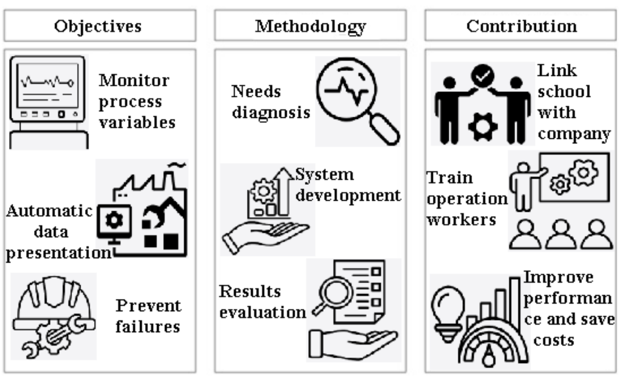
Abstract

ANDON systems have been very useful in different industrial processes, since through visual management they alert in real time about present problems, reducing response time, downtime and increasing efficiency. These systems are generally manual and depend on the manipulation of operators; their operation is desired to be automatic; this can be achieved using elements that capture process variables and programmable controllers and display elements. This work presents an application in a plastic injection company to solve a problem of monitoring pressure and temperature services that caused downtime in production lines. The use of sensors is proposed for the acquisition of variables and screens to present information through visualization tools available in PLC for remote monitoring, acquisition and presentation of data so that solutions can be applied immediately, reducing downtime. and saving costs.



Monitoring, PLC, System

Resumen

Los sistemas ANDON han resultado muy útiles en distintos procesos industriales, ya que a través de una gestión visual alertan en tiempo real sobre los problemas presentes, reduciendo el tiempo de respuesta, tiempos de inactividad e incrementando la eficiencia. Estos sistemas generalmente son manuales y dependen de la manipulación de los operadores, se desea que su funcionamiento sea automático, esto se puede lograr utilizando elementos captadores de variables del proceso y controladores programables y elementos de visualización. Este trabajo presenta una aplicación en una empresa de inyección de plástico para resolver un problema de monitoreo de servicios de presión y temperatura que provocaba tiempos de paro en líneas de producción. Se propone el uso de sensores para la adquisición de variables y pantallas para presentar la información a través de herramientas de visualización disponibles en PLC para el monitoreo, adquisición y presentación de datos a distancia para que las soluciones puedan aplicarse inmediatamente, reduciendo el tiempo de inactividad y ahorrando costos.

Monitoreo, PLC, Sistema

Citation: Sotelo-Martínez, Samuel, Ocampo-Martínez, Rafael, Olivo-Flores, Marco Antonio and García-Mendoza, Rufino. [2024]. Implementation of a system ANDON for the utilities department in a plastic injection plant. Journal of Technical Invention. 8[21]-1-7: e20811107.

Introduction

ANDON is a visual and auditory communication system used in industry that informs operators which activities they need to perform to resolve problems in the production line as soon as they occur, to increase quality, production, and reduce costs [1]. First used in Japan in 1970, these systems support decision-making in lean manufacturing and are applied in industry at different levels: manual, semi-automatic, and fully automated. In addition, they are classified by the type of information they provide, such as process status information, product quality information, and operator safety information [2].

Researchers in industrial processes have presented work analyzing three fundamental Lean Manufacturing tools: Visual Management, Poka Yoke, and the ANDON system, which help in the production process by preventing errors in the manufacturing industry, concluding that these three tools positively impact economic sustainability [3].

Box 1

Figure 1
Industrial ANDON type signal tower.¿

Applications with manual ANDON systems limit response time and rely entirely on the operator's interpretation and evaluation of problems, which is not always the most efficient and timely. Additionally, these systems generally display the error or failure signal after the issue has occurred, necessitating corrective maintenance and process recovery to resume production, resulting in production downtime.

Therefore, the development of an automatic ANDON system application is presented, which displays process status information for different areas of the plant.

This system allows the identification or visualization of undesirable trends before annunciating a failure signal, consequently enabling corrective action to be taken to prevent downtime. Previous work has taken the basic principle of the ANDON system but modified it by incorporating computer assistance. Due to the industrial plant's infrastructure, the visibility of indicator lights can be challenging, so an auxiliary department for handling process status signals has been implemented, consequently improving plant performance [4].

This project was developed for an automotive parts company. Air compression, chiller water condensation, and cooling tower operations are essential services required for the proper operation of the injection and blow molding process. In the plant layout, the service area is located outside the injection plant, and it is important to constantly monitor these services in real time from the maintenance area to prevent a service failure that could cause partial or total production downtime. This design addresses monitoring and downtime issues. It acquires pressure and temperature readings and utilizes an Ethernet (EtherCAT) fieldbus available in the plant as a communication medium to collect and display the value of these variables in real time anywhere within the plant. This protocol is one of the new real-time Master/Slave functionality networks, with an open standard capable of handling up to 1000 I/O points within 30 µs response time. Using twisted pair or fiber optic cables in Full Duplex communication, it achieves >90% efficiency with a speed of 200 Mbits/s [5].

The ANDON system is enhanced by combining it with other technologies such as programmable logic controllers (PLCs), resulting in projects enabling continuous process monitoring. Using predictive maintenance, these projects maintain production volume and prevent downtime [6]. For this designed system, a Beckhoff PLC was used, a brand that offers visualization tools for creating control panels.

The document is structured into five sections. Section II details the automatic ANDON system, including a comprehensive description of its components. Section III outlines the complete functional architecture of the system through a block diagram. Sections IV and V subsequently present the empirical results and their respective analyses and conclusions.

ISSN: 2523-6792
RENIECYT-CONAHCYT: 1702902

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Integration of the ANDON System

In designing this project, various elements comprise the ANDON system are considered. The HMI (Human-Machine Interface) will utilize a commercial monitor to display process data to users. In addition, this monitor includes a touch screen, allowing control of the system's start and stop operations. The design of this interface must be intuitive, efficient, and user-friendly, combining user needs with machine capabilities [7].

The sensors interact with the process variables and provide a proportional electrical signal as input to the control system. Three J type thermocouples and a GP-M series pressure sensor from Keyence will be used. The supervisory system will be a computer responsible for collecting process data and sending instructions via the command line. For this project, the computer can be online with the system and perform supervisory functions; however, the system can operate independently of the computer. The PLC, or programmable logic controller, will host the control program and act as the field device receiving the signals from the field sensors, properly formatting these signals, and displaying the data on a visualization panel. A Beckhoff PLC, model CX9020, will be used. This controller features a 1GHz ARM Cortex-A8 processor, an embedded Windows 7 operating system, and communication peripherals including RJ45, DVI-D, and USB [8]. This model is suitable for the application as it natively includes a visualization tool that allows the creation of control panels through the TwinCAT program.

Box 2

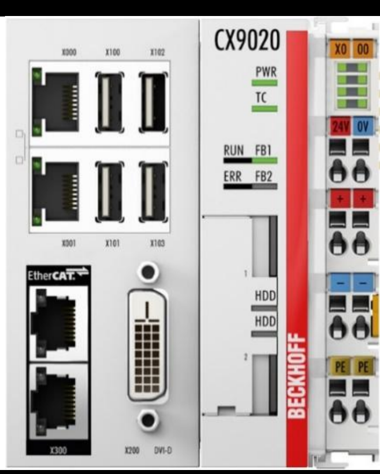

Figure 2
PLC Beckhoff CX9020

Next, a communication network is necessary to link the PLC with the computer, HMI, and other devices within the plant network. This project uses the EtherCAT (Ethernet for Control Automation Technology) protocol, an Ethernet-based fieldbus developed by Beckhoff Automation. It is designed for fast response control applications, featuring a synchronized, deterministic, and real-time protocol that maintains a high speed of 100 Mbps and short communication cycles of 12 μs. It employs a master-slave communication model [9]. For this project, only one master device containing the programmable logic will be used.

Box 3

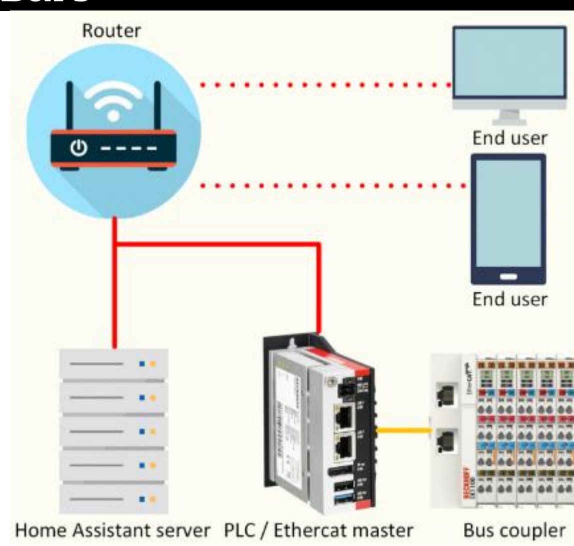

Figure 3
Integration of the ANDON System

The integration of the proposed ANDON system is shown in Figure 3. The process variable sensing elements, such as thermocouples and pressure sensors, are linked to the PLC controller via a bus coupler equipped with cards for processing digital and analog I/O signals. The dedicated controller receives the input signals and updates the control outputs based on the user-developed program. The generated data is transmitted through the EtherCAT network, which is compatible with the plant's Ethernet server network. Once on the network, the data can be accessed by the end user via wired or wireless means through an interconnection device like a router.

ISSN: 2523-6792
RENIECYT-CONAHCYT: 1702902

Configuration and Operation of the ANDON System

The PLC peripheral connections include:

Digital Inputs: Three digital inputs for start, stop buttons, and an auxiliary contact for power supply failure detection.

Digital Outputs: Four digital outputs for red, yellow, green, and blue lamps.

Analog Inputs: One analog input for the compressor pressure sensor with a standard signal of 0 to 10 V, proportional from -0.21 to 1 MPa, and three analog inputs for J type thermocouples to measure ambient temperature, chiller temperature, and cooling tower temperature.

Temperature readings are performed using the EL3318 module, which is a specialized module for connecting to eight thermocouples, featuring 16-bit resolution, automatic linearization, and cold junction compensation.

Box 4

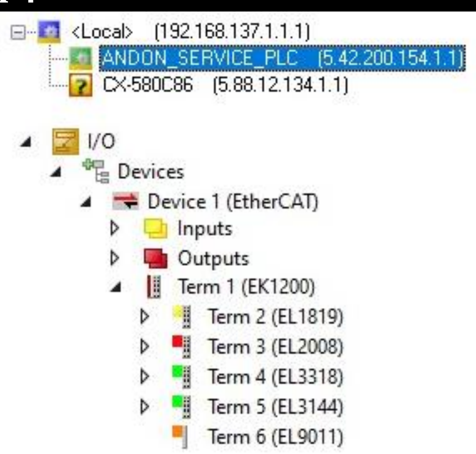

Figure 4
Network and Communication Bus Configuration.

The PLC controller is configured on the industrial Ethernet network by assigning parameters such as name, connection time, and a static IP address within the same subnet to join the network. The procedure for incorporating the device into the network is based on commonly used protocols for integrating automation systems into control networks [10].

The variables used in the ladder logic programming for receiving and generating control signals are registered. Depending on their nature, these variables are declared as integers, Booleans, and real numbers. See Figure 5 for a detailed view of the ANDON system variables.

Box 5

andon.programa.control

Expression	Type	Value	Address
presion	INT	9475	%I*
chiller	INT	629	%I*
torre	INT	488	%I*
ambiente	INT	482	%I*
lamp_verde	BOOL	TRUE	%Q*
lamp_ambar	BOOL	FALSE	%Q*
lamp_roja	BOOL	FALSE	%Q*
compresor_apagado	BOOL	TRUE	%I*
inicio	BOOL	FALSE	%M*
paro	BOOL	FALSE	%M*
presion_escalada	REAL	5.78325748	%M*
chiller_escalada	REAL	10.5633583	%M*
torre_escalada	REAL	21.9647751	%M*
ambiente_escalada	REAL	23.8292141	%M*

Figure 5
ANDON System Variables

During the execution of the ANDON system, the variables are assigned a name, type, value, and memory address. The user interaction indicators of the ANDON system are configured according to the values required by the process. For the compressor pressure, the minimum value is 5.5 Bar, and the maximum is 7.5 Bar. The expected temperature for the chiller is a minimum of 7°C and a maximum of 16°C, while the cooling tower temperature should be between 12°C and 28°C. Ambient temperature does not have comparison parameters and is used exclusively for monitoring, as it depends on the time of day and climatic conditions.

The programming logic used in the controller for the operation of the designed ANDON system is represented in the diagram in Figure 6. In this diagram, a red lamp lights up when a compressor power supply failure is detected, a yellow lamp lights up when there is a failure in reading any of the variables, a green lamp lights up when at least one of the variables is outside the desired preset range, and finally, a blue lamp lights up to indicate that the pressure and temperature parameters are within the normal range. This logic executes sequentially if the start button is activated.

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RENIECYT-CONAHCYT: 1702902

Box 6

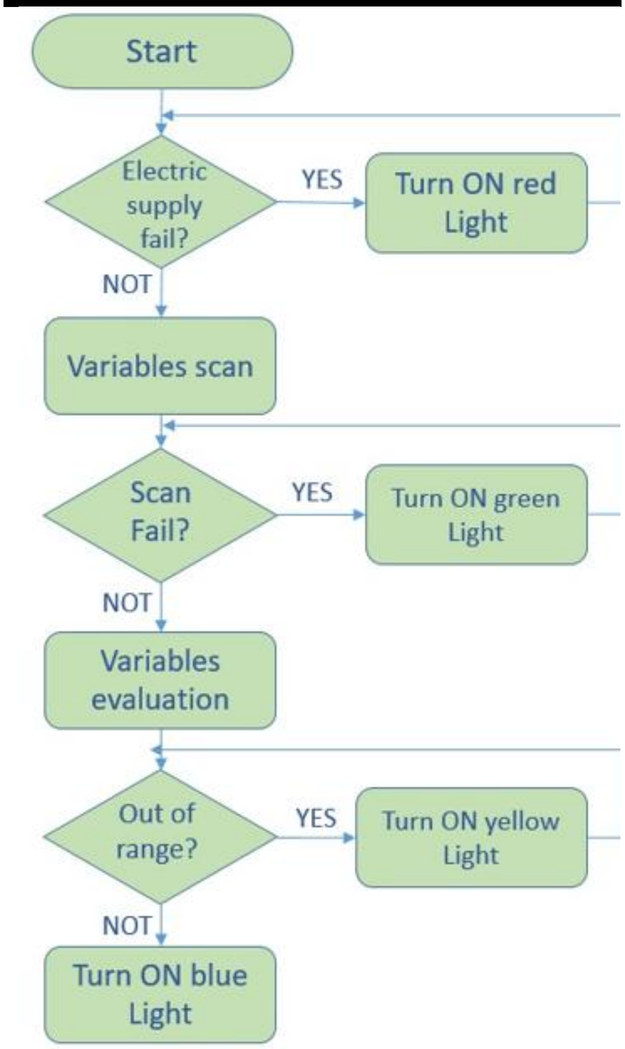

Figure 6
ANDON System Operation Diagram

Finally, the performance of the ANDON system is not only displayed via the local signal tower but also displayed onto a monitor via a digital HMI control panel designed with the TwinCAT tool. This tool allows for the creation of graphics linked to process variables, which can be made available as a web page. This enables remote monitoring and operation over the internet from various network access points.

Results

The final design of the ANDON system visualization, operating and running online, is shown in Figure 7. This graphic can be accessed by any internet-connected device for remote monitoring and operation.

Box 7

Figure 7
ANDON System Graphical Panel.

Access to this graphic is available from any point in the production plant via screens that display graphs and numerical indicators showing real-time values of process variables. After installing the system in the service area of the injection plant, tests were conducted to compare the values provided by the ANDON system with those obtained from calibrated measurement instruments, yielding results as shown in Table 1.

Box 8

Table 1
ANDON System Test Measurements vs. Calibrated Instruments

Hora	Presión Compresor		Temperatura Chiller		Temperatura Torre		Temperatura Ambiente	
	ANDON	Real	ANDON	Real	ANDON	Real	ANDON	Real
8:00	6.2 Bar	6.2 Bar	8.1 °C	8.4 °C	15.5 °C	15.7 °C	18.5 °C	18.7 °C
9:00	6.1 Bar	6.0 Bar	8.5 °C	8.9 °C	17.2 °C	17.5 °C	29.2 °C	29.5 °C
10:00	6.0 Bar	5.9 Bar	9.1 °C	9.3 °C	18.9 °C	19.1 °C	20.4 °C	20.9 °C
11:00	5.9 Bar	5.7 Bar	9.7 °C	10.0 °C	20.6 °C	20.9 °C	21.6 °C	22.0 °C
12:00	5.8 Bar	5.6 Bar	10.5 °C	10.8 °C	21.9 °C	22.3 °C	23.9 °C	24.2 °C
13:00	5.8 Bar	5.7 Bar	11.0 °C	11.4 °C	22.2 °C	22.6 °C	25.3 °C	25.6 °C
14:00	5.9 Bar	5.8 Bar	12.3 °C	12.8 °C	23.3 °C	23.8 °C	27.1 °C	27.4 °C
15:00	6.0 Bar	5.8 Bar	12.9 °C	13.5 °C	24.2 °C	24.6 °C	29.7 °C	30.3 °C

Source: Own elaboration

To verify the effectiveness of this system, the relative error between the values obtained by the ANDON system and the expected values measured with instruments is calculated. The following formula is used to calculate this parameter:

$$er = \frac{\sum_0^n \left| \frac{Xi - Xv}{Xv} \right|}{n} \quad (1)$$

Where:

n = total number of data points
Xi = value acquired in each iteration.
Xv = expected value.

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The relative error for each variable was 0.0304 for pressure, 0.0330 for chiller temperature, 0.01595 for cooling tower temperature, and 0.01564 for ambient temperature. This demonstrates that the proposed system has a sampling accuracy between 96% and 98%.

Conclusions

This article demonstrates the implementation of an automatic ANDON system for monitoring process variables. The data acquisition system is implemented in a PLC controller with a bus coupler to receive pressure and temperature data. Information is transmitted over an Ethernet network and displayed on screens to the end user for the prevention of failures and downtime.

By utilizing the EtherCAT protocol, the system benefits from high transmission speed and low latency. Additionally, the system can integrate a database for information storage and historical data retrieval.

The system was verified by calculating the relative error between the obtained values and the expected values, demonstrating a sampling accuracy between 96% and 98%. It is validated that the system can be applied to other areas of the plant with different process variables.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Sotelo Martínez, Samuel: Contributed to the project idea, design, implementation and installation of the project in the company's plant.

Ocampo Martínez, Rafael: Contributed to the technical advice, research method and project documentation.

Olivo Flores, Marco Antonio: Contributed to design validation, research method and translation support.

García Mendoza, Rufino: Contributed to methodological review, project monitoring and technique advice.

Availability of data and materials

The values presented in section VI were measured on March 14, 2024. The availability of this data is reserved for the authorization of the company.

Funding

The project was financed by two collaborators: the material and equipment by the company EXO-S and the design, development and installation by the university UTSJR.

Acknowledgements.

We would like to extend our special thanks to EXO-S Industries for allowing the development of the project within their facilities and for providing the necessary materials, tools, equipment, and infrastructure for the implementation of the project.

Abbreviations

EtherCAT: Ethernet for Control Automation Technology

HMI: Human Machine Interface

Mbps: Mega Bits per Second

PLC: Programmable Logic Controller

USB: Universal Serial Bus

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ISSN: 2523-6792
RENIECYT-CONAHCYT: 1702902

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