

Industrial Automation of Fire-Fighting System with the Aid of Programmable Logic Controller PLC: A Technical Proposal

Abubakar, Hassana Ojochide, Zaharuddeen Haruna, Shamsuddeen Yusuf
Department of Computer Engineering,
Faculty of Engineering,
Ahmadu Bello University, Zaria, Kaduna State.

ABSTRACT

Fire-fighting methods are pivotal in safeguarding property, human lives, and industrial equipment within commercial enterprises. This technical report explores the automation of fire-fighting systems for industrial settings by leveraging Programmable Logic Controller (PLC) technology. The study is motivated by the aspiration to design a highly reliable system employing Siemens S7-1200 PLC technology, complemented by monitoring software, TIA (Totally Integrated Automation) Portal Version 16, for PLC program development, and PLCSIM for simulation. The proposed system integrates three flame sensors as inputs to actively sense and collect real-time data from the field. The PLC functions as the central controller for fire management, with three distinct outputs: an alarm, a siren for auditory alerts, and an automated water spray system designed to promptly extinguish fires. This comprehensive solution serves as a critical protective measure within industrial plants. The successful implementation of this automated system streamlines the operation sequence, minimizing the need for human intervention. Consequently, it enhances the accuracy and speed of the fire-fighting process, further fortifying the safety and security of industrial facilities.

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INTRODUCTION

Industrial Control Systems (ICS), commonly referred to as Process Control Systems (PCS), play a pivotal role in scrutinizing and optimizing manufacturing processes as they progress along the production line. A PCS represents the overarching framework encompassing a cohesive amalgamation of hardware and software components interconnected within the industrial infrastructure. At its core, a PCS comprises three fundamental elements: Sensors, Controllers, and Actuators, rendering it a conceptually straightforward yet indispensable entity in industrial automation.

The sensors within a PCS serve as the initial data gatherers, diligently collecting pertinent information from specific sources, typically associated with various industrial processes. This data is then transmitted to the controller, where it undergoes further processing in accordance with a user-defined program. The controller, acting as the intelligent

orchestrator, follows the programmed instructions and subsequently forwards the processed data to the actuator through an output device. The actuator's role is to implement any necessary corrective actions in response to the processed information, ensuring that the industrial system operates optimally.

This triad of sensors, controllers, and actuators is not limited to large machinery but can be seamlessly integrated into various equipment to monitor and troubleshoot manufacturing processes, underscoring its adaptability and versatility.

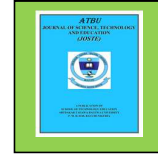
While the hardware and software components are integral to PCS, the focal point of PCS alarm management transcends the mere technical aspects. Rather, its primary objective lies in exercising control over the work process itself. In essence, the PCS alarm system is a valuable instrument that empowers industrial operators to maintain operational integrity.

Corresponding author: Abubakar Hassana Ojochide

✉ habubakar.engineering@abul.edu.ng

Department of Computer Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria.

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A well-constructed PCS alarm system serves as a sentinel, alerting human operators with timely, meaningful notifications. These alerts are strategically positioned to enable operators to initiate corrective actions effectively, safeguarding the industrial process from potential disruptions and enhancing overall productivity. The adaptability and customization of each PCS to cater to the specific needs of different industries make it a cornerstone of automation in various sectors, contributing to enhanced efficiency and reliability in industrial operations.

LITERATURE REVIEW

In the context of fire safety, an automatic fire-fighting system, also known as an automatic fire suppression system, represents a technology-driven strategy designed to protect both people and property. This system operates autonomously, without requiring human intervention, and is proficient at detecting, managing, and extinguishing fires. Known for its reliability, versatility, and ease of integration with other devices, Programmable Logic Controllers (PLCs) are commonly employed in the automation of fire-fighting systems. The objective of this research proposal is to delve into the extensive body of research concerning automatic fire-fighting systems.

Kwon et al. (2008) made strides in the development of a Fire Detection System, which relied on sensor-based technologies capable of autonomously detecting smoke and temperature variations. This system, coupled with fuzzy theory, found application in industries, particularly in areas susceptible to fire outbreaks. While generally effective, it fell short in environments demanding precision and reliability, such as expansive factories, electric power plants, and telecommunication facilities. These shortcomings prompted an exploration of alternative solutions employing camera image processing to address these issues, thus enhancing accuracy and dependability.

Asif et al. (2014) undertook a comprehensive review of Fire Detection Systems and devised an SMS-Based Automated, Instant-Responsive Fire Alarm System. Their study encompassed the design and development of a microcontroller-based automatic fire alarm system, specifically tailored

for residential areas and commercial buildings. This system aimed to expediently notify property owners of fire incidents via SMS over the GSM network. Utilizing semiconductor-type smoke sensors and linear integrated temperature sensors, the system monitored the presence of smoke and changes in temperature, with data processing executed by an ATmega8L AVR microprocessor. The research included practical testing to evaluate the system's performance.

In another study, Kumar and Naga (n.d.) introduced an automatic fire alarm system based on wireless sensor networks. Their research recognized the significant risks posed by fire hazards and emphasized real-time monitoring, early warning signals, and surveillance as crucial components of an effective fire alarm system. Their approach involved deploying a network of sensors throughout high-rise buildings to continuously monitor smoke concentration and temperature. This distributed network transmitted data to a central monitoring system via a self-organizing hierarchical wireless sensor network, a design optimized for operational efficiency and precision.

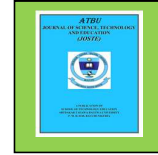
Sen et al. (2015) proposed a low-cost automated fire control and detection system, integrating smoke and heat detection, flame detection, and control systems. Employing various electrical and electronic devices, this system detected the presence of smoke and temperature changes within extinguishable limits. Upon detection, it automatically activated a relay to trigger sirens or alarms and, in some cases, water sprinklers. Additionally, the system could send Short Message Service (SMS) notifications to registered mobile phones, enhancing its effectiveness in fire incident management. Wibowo and the Institute of Electrical and Electronics Engineers (2018) introduced a novel fire detection system that relied on leaky gas concentrations to predict potential fires and explosions. The system employed fire detectors that measured leaked gas concentrations and triggered alarms when necessary. However, data analysis challenges were noted, and the research indicated the need for improvements in real-time data processing.

Corresponding author: Abubakar Hassana Ojochide

✉ habubakar.engineering@abul.edu.ng

Department of Computer Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria.

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Babar et al. (n.d.) explored an automated fire detection and control system employing Programmable Logic Controllers (PLCs). This system incorporated various sensors, such as smoke detectors and temperature detectors, to detect and control fires. When a fire risk was detected, the system responded by sounding alarms and activating extinguishing equipment. It offered several advantages, including a compact design, reduced panel manufacturing errors, and enhanced logic manipulation.

Khan et al. (2023) presented an innovative automation system for fire detection and control in commercial buildings using Programmable Logic Controllers. This system featured sensors capable of detecting flames, prompting the automatic activation of water pumps and fire alarms. Simultaneously, exit doors were automated to enhance evacuation safety during fire incidents.

The Institute of Electrical and Electronics Engineers and Shenyang shi fan da xue (2020) devised a factory fire alarm system capable of instantaneously detecting fires and transmitting alarms, thereby mitigating losses resulting from fire incidents. The system combined smoke, temperature, and fire modules and utilized a wireless communication network to relay data to a central monitoring system.

Wei et al. (2020) focused on designing an integrated fire alarm system for an integrated pipe gallery, emphasizing early-stage fire prevention. The system employed various sensors to monitor environmental conditions and mitigate fire hazards within the pipe gallery, enhancing overall safety.

Xie and Haoming (2021) introduced a home fire alarm system that relied on a combination of microcontrollers and sensors. This system efficiently detected fires and flames using gas, temperature, and flame sensors, triggering alarms and other safety measures when necessary. Das et al. (2021) aimed to optimize fire control and response pumps by designing a PLC-based fire suppression system. Their research highlighted the efficacy of PLCs in enhancing control and scalability, leading to increased reliability and convenience in fire suppression.

Lastly, K.C. et al. (2015) contributed a computer vision-based fire detection and suppression system for manufacturing industries, leveraging a single camera and multiple extinguishing chemical control valves. Their system employed the Neuro-Fuzzy algorithm to detect fire pixels and automatically activate control valves, achieving a high degree of accuracy in fire detection and suppression.

Problem Statement

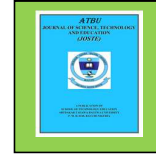
In industrial settings, the occurrence of a fire outbreak can pose a severe threat to individuals, property, and machinery. Often, traditional firefighting methods may prove inadequate, especially in complex industrial environments. Consequently, there is a pressing need for an efficient and automated fire-fighting system capable of rapidly detecting and extinguishing fires before they can cause significant damage.

The central focus of this scenario lies in the design and implementation of an industrial automation system for fire control, employing a Programmable Logic Controller (PLC). This system's primary functions include monitoring a multitude of sensors and promptly identifying fire incidents. Depending on the location and severity of the fire, the PLC should activate the corresponding fire suppression system, such as water sprinklers.

This system's development should encompass the provision of timely alarms and evacuation signals in the event of a fire outbreak, ensuring the safety of personnel. Moreover, it should possess the capability to establish a real-time connection with the central control center, offering continuous updates on the fire's status and the effectiveness of the suppression system.

Therefore, the objective of this research is to devise an automated fire-fighting system that can swiftly and effectively detect and extinguish fires in industrial settings, thereby minimizing harm to property, machinery, and individuals. To be a practical and viable solution for extensive industrial applications, this system must be reliable, cost-effective, and straightforward to maintain.

The existing industrial automation fire-fighting system is beset by limitations, characterized by sluggish and inaccurate fire



detection and an inadequate response system. Overcoming these challenges necessitates the development of an industrial automation system capable of swiftly identifying fires by employing three flame sensors as inputs and activating an alert, siren, and water sprinkler through a voting system. By initiating the water sprinkler, this system ensures real-time fire detection and a coordinated response, substantially reducing the likelihood of fire-related accidents and mitigating the risks associated with the loss of life and property. This advanced system guarantees reliability, accuracy, user-friendliness, and ease of upgrades, thanks to its utilization of a PLC.

The primary aim of this project is to design and install an industrial automation system employing three flame sensors as inputs. These sensors will detect fires through a voting system, and the Siemens S7-1200 PLC will serve as the output device, triggering an alarm, sounding a siren, and activating the water sprinkler. Such a system is poised to significantly enhance the efficiency and safety of fire management in industrial environments.

The proposed system's design will feature the utilization of a Siemens S7-1200 Programmable Logic Controller (PLC) to process data from the flame sensors. By making voting-based decisions, this system will promptly alert nearby personnel to the fire, activate alarms and sirens, and initiate the water sprinkler, further enhancing the effectiveness and safety of fire control in industrial settings.

Aim and Objectives

The aim of the thesis is to propose industrial automation of fire-fighting system with the aid of programmable logic controller PLC.

1. To design a fire detection system that makes use of flame sensors to locate and detect fires.
2. To create a PLC-based control system that can take input from the fire detection system and autonomously activate the water sprinkler system and fire suppression devices.
3. To link the PLC system with additional industrial control systems (such as a speed governor system) to guarantee

that all equipment would operate as intended in the event of a fire.

4. To put in place an alarm system that notifies staff members and rescue personnel in the case of a fire.
5. Should carry out thorough testing and validation to make sure the system functions accurately and dependably in all conceivable scenarios.
6. To give staff members thorough instruction on how to operate and maintain the automatic fire fighting system.

SYSTEM REQUIREMENT

The design requirements for the industrial automation fire-fighting system encompass several key components:

1. **Sensor Inputs:** The system necessitates the inclusion of three digital inputs, specifically flame sensors, which are pivotal for detecting potential fire incidents.
2. **Output Devices:** Three digital outputs are integral to the system, comprising an alarm, a siren, and a water sprinkler. These components play a vital role in swiftly responding to fire incidents.
3. **PLC Hardware:** The heart of the system is the Siemens S7-1200 PLC, comprising a CPU, input module, output module, power supply, and a programming device. This PLC forms the core control unit for the entire system.
4. **Software Integration:** The system's functionality is contingent upon the integration of software components, including monitoring, programming, and hardware configuration software, namely the Siemens TIA (Totally Integrated Automation) portal, which facilitates seamless management and control.
5. **Simulation Capability:** For testing and validating the system's operation, the inclusion of simulation software, such as PLCSIM, is crucial. This allows for real-world scenario testing in a controlled environment.

The system operates by utilizing three flame sensors and an RTD (Resistance Temperature Detector) as inputs, which collectively enable the detection and management of flames or fires within an

industrial process or environment. This is achieved through a sophisticated voting system that enhances the system's accuracy and reliability in fire detection and response.

The system's output functionality is equally robust, utilizing three distinct elements: an alarm to provide visual warnings, a siren for audible alerts, and an automatic water spray

system. This comprehensive suite of outputs ensures that the system can autonomously and swiftly quench fires without human intervention. This proactive approach to fire management serves as an invaluable protective measure in industrial environments and plants, greatly enhancing safety and security.

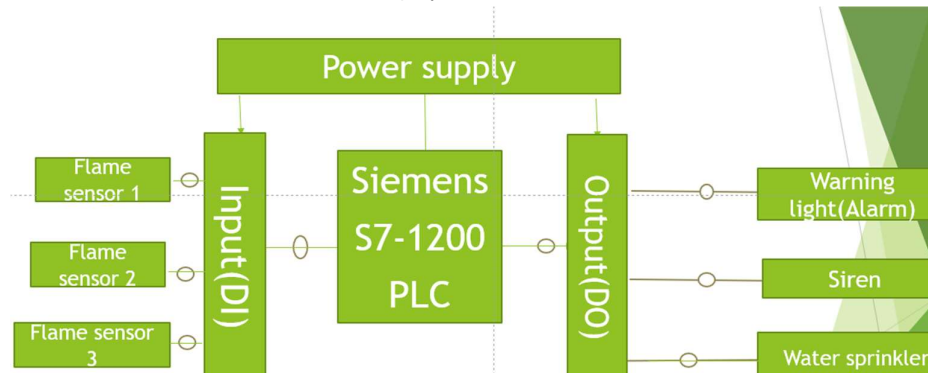


Fig. 1: below shows the block diagram.

Selection of the appropriate PLC: Siemens S7-1200 PLC can handle the input and output requirements of this system, and has the necessary programming capabilities to implement a voting system.

Hardware design: The hardware components of the system, including the PLC, flame sensors, alarm, siren, and water sprinkler would be designed on the TIA portal software and would be compatible with the PLC and should communicate with it.

Software development: PLC program that will control the system would be written on the Siemens TIA portal using ladder logic program. It includes, programming the inputs from the three flame sensors or RTDs, implementing the voting system logic, and controlling the outputs to activate the alarm, siren, and water sprinkler.

Testing the system: The system will be thoroughly tested to ensure it meets the requirements and is functioning as intended. The flame sensors, will be tested, the voting system, and the outputs to ensure that they are triggered appropriately.

1. When any of the three flame sensors senses fire, an alarm or warning light comes on.
2. When any of the two combinations senses fire (either flame sensor 1+2, or 2+3, or 3+1), a Siren Sounds.
3. When all the three signals come up (flame sensor 1+2+3 at a time), a Water Spray System should start immediately to put off the fire automatically.

A voting system is used in this system to determine the certainty or assurance of the fire, one of the sensors might malfunction, or a lightning or thunder might trigger its contact to close and thereby bringing a false alarm. But with this voting system, all 3 sensors cannot malfunction at the same time.

Installation of the system: The fire-fighting system will be installed in the desired location, following all safety regulations and guidelines.

Monitoring and maintaining the system:
Regular monitoring and maintenance of the fire-fighting system would be done to ensure that it

is functioning properly and is ready to respond to any potential fires.

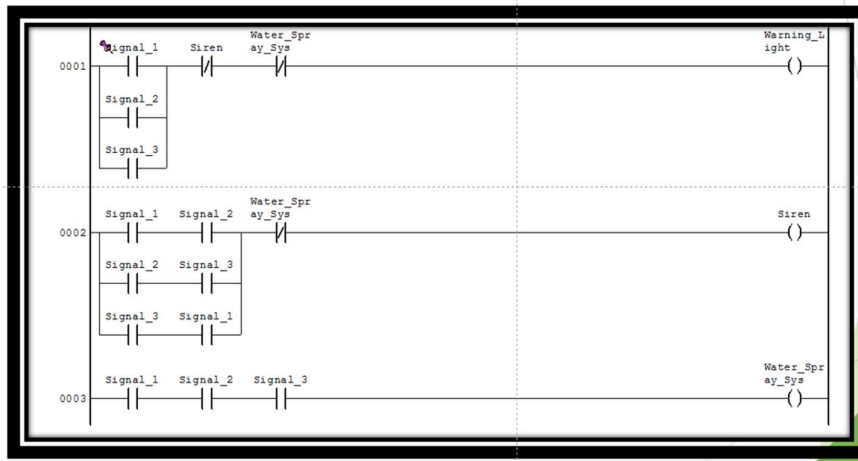


Fig. 2: The simulated ladder logic diagram.

CONCLUSION

The industrial automation of a fire-fighting system, featuring three flame sensors as inputs operating on a voting system, coupled with alert, siren, and water sprinkler outputs, stands as a reliable and efficient fire safety solution for industrial environments. Key to this system's rapid fire detection is the integration of three flame sensors and a voting system, a pivotal measure in preempting potential threats. In the event of a fire incident, the incorporation of an alarm, siren, and water sprinkler guarantees swift and appropriate responses for fire suppression.

The Siemens S7-1200 PLC, renowned for its dependability, durability, and advanced capabilities, serves as an exemplary choice for this application. It orchestrates the seamless and effective operation of the entire system, ensuring that it functions with precision and reliability.

In summary, the Siemens S7-1200 PLC, coupled with the three flame sensors and associated outputs, is a robust and dependable fire safety solution specifically tailored for industrial settings. It plays a vital role in safeguarding people, property, and equipment by promptly identifying and mitigating fire risks.

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✉ habubakar.engineering@abul.edu.ng

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