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Research Paper

AN INTERNET OF THINGS (IOT)-BASED INDUSTRIAL MONITORING SYSTEM THAT USES AN ESP DEVICE TO PICK AND SORT ITEMS FROM A CONVEYOR BELT

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Abstract - Modern manufacturing settings cannot function without industrial automation, which has proven crucial for increasing output per worker, decreasing the need for human intervention, and guaranteeing the security of machines. Traditional industrial systems often use isolated components to track machines, identify potential dangers, and manage materials, which leads to inefficient communication, hindered collaboration, and restricted ability to oversee operations remotely. An Internet of Things (IoT) industrial monitoring system that uses an ESP device to select and sort items off a conveyor belt is presented in this study as a solution to these problems. A single integrated platform unifies intelligent material handling and industrial parameter monitoring in the suggested system. When it comes to continual machine safety & health monitoring, an ESP controller serves as the core unit that gathers information gathered by a voltage detector, a temperatures sensor, and fire sensor. A robotic pick-and-place system that uses servos and a conveyor belt work in tandem to automate the sorting and handling of objects. Notifications are sent to an Internet of Things (IoT) online system for remote monitoring when the controller detects abnormal circumstances, for example excessive heat, voltage fluctuation, or fire. The warnings are generated by a buzzer and the LCD display is updated. Connectivity to the internet of things allows for smart automation and adaptable manufacturing processes, including control of the robotic arm and conveyor. To address the needs of smart design, workplace security, and automated pick-and-sort, the suggested system offers a small, affordable, and scalable solution.

Keywords - Industrial monitoring, smart manufacturing, temperature, voltage, and ESP controllers; pick-and-place robots; conveyor belts; and industrial automation are all part of the same picture.

I. INTRODUCTION

The use of interconnected digital communication networks, sensors, control units, and machinery is quickly becoming the norm in industrial production systems in an effort to improve efficiency, quality, and security. Automation in today's industries encompasses more than just mechanized processes; it also allows for remote supervision, intelligent material management across production lines, early identification of abnormalities, and real-time monitoring of equipment health. Machines also embedded controllers may now gather operational data, connect via networks, and facilitate remote judgment in industrial settings, all thanks to the rise of the World Wide Web of Things (IoT), which has further expedited this shift.

Material handling and industrial monitoring are often seen as distinct tasks in traditional manufacturing facilities. Manual or isolated safety circuit monitoring of machine health parameters like power supply, thermal, and fire conditions is common, while simple conveyor equipment or manual labor are used for material handling duties like sorting and item transfer. Quite a few restrictions result from this split. To begin, there is a risk that aberrant machine conditions may go undetected for too long, which can result in broken equipment, lost production time, or even danger to workers. Second, industrial procedures become inconsistent and throughput is reduced due to human sorting and object handling. Third, operators can't see how the system is doing in real time or react fast to problems since there isn't a centralized monitoring system.

Through the integration of cyber-physical systems, the Industrial Web of Things (IIoT), computing in the cloud, big data analysis,, and artificial intelligence, the arrival of Industry 4.0 has revolutionized conventional manufacturing into a data-driven ecosystem that is more interdependent, intelligent, and intelligent. Industry 4.0 proposes cross-process coordination, automated decision-making, and real-time communication between machines, as opposed to the traditional industrial model that depends mostly on standalone units and human oversight. Due to this change, there has been a flurry of activity in the field of smart manufacturing frameworks, IMS, AI, and digitalized production settings. Connected industrial systems that may optimize operations, monitor machine conditions, and increase production efficiency via intelligent control and real-time data sharing have thus been more and more emphasized in recent literature.

Much of the published work on Industry 4.0 is devoted to outlining its basic ideas and technical framework. The increasing importance of the Internet of Things (IoT), machine learning, information analysis, machine learning, and integrating digitally in contemporary industrial systems was highlighted in a study of key Creative 4.0 technologies & their uses in production conducted by Javaid et al. [1]. By examining the enabling applications, technologies, and design principles of Industry 4.0 for intelligent manufacturing scenarios, earlier survey research by Lu and Hermann et al. [4], [5] laid the conceptual groundwork for the notion. In addition, Lee et al. [6] suggested an architecture for cyber-physical systems (CPS) that would be used in manufacturing based on Industry 4.0. This design would highlight the close relationship among physical production processes and computational intelligence. In a similar vein, Lu produced an in-depth analysis of CPS-based Industry 4.0, demonstrating how cyber-physical integration is a key component of contemporary industrial automation [13]. Research from these sources demonstrates that smart industrial surveillance and control are the cornerstones of Industry 4.0, which in turn is based on the merging of computerized discourse, sensing, automation, plus physical production processes [1, 4–6], [13].

The function of the IIoT in developing linked production systems and smart factories is another important area of study. A state-of-the-art research on Industrial IoT including smart manufacturing in light of Industry 4.0 was given by Wan et al. [3]. The study demonstrated how intelligent production environments may be supported by connected sensors, equipment, and industrial networks. In a separate study, Wan et al. presented the idea of defined by software industrial IoT, which enhances the flexibility and scalability of industrial systems via flexible communication and control methods [11]. focused their discussion of Industry 4.0 smart factory implementation, Wang et al. [8] zeroed focused on the integration of automation technologies, communication systems, and sensor networks into manufacturing lines. In addition, Zheng et al. provided scenarios and conceptual frameworks for intelligent production systems, demonstrating how data-driven control, linked equipment, and monitoring units might facilitate more efficient and adaptable industrial processes [14]. Based on its support for distributed sensing, machine-to-machine communication, continuous monitoring, and real-time industrial automation, IIoT has emerged as a key component of smart manufacturing, according to these research [3, 8, 11, 14].

The function of cloud computing, AI, and intelligent computing in manufacturing settings has been the subject of increased study due to the proliferation of linked industrial systems. The significance of AI in intelligent decision-making, scheduling, process optimization, predictive maintenance, and cloud-assisted smart factories was emphasized in the extensive study on AI for smart factories by Wan et al. [2]. In their discussion of internet-based fabrication tools and big data analytics, Lu and Xu demonstrated how integration with the cloud facilitates the sharing and analysis of production data and industrial resources, paving the way for on-demand manufacturing services [9]. In addition to remote data storage, these advancements show that analytical methods, artificial intelligence, and service-oriented manufacturing may all benefit from cloud-assisted industrial systems. For industrial systems of monitoring, this change is crucial because it allows for the transformation of continuous sensor data into useful insights for optimization of production, quality control, and maintenance planning [2, 9].

Analytics in Industry 4.0 settings, big data, and industrial data management are topics that have attracted a considerable amount of research. Yin and Kaynak highlighted the significance of big data for contemporary industries and went over the difficulties of dealing with large amounts of data, analyzing them, and using industrial intelligence [7]. In their analysis of Industry 4.0 data management, Raptis et al. [10] highlighted challenges including data storage, integration across diverse industrial platforms, real-time processing, and interoperability. Big data for physical and cyber systems in Industry 4.0 was also examined by Da Xu and Duan, who demonstrated the importance of data-driven methods for industrial monitoring, control, including intelligent decision support [15]. Taken together, these studies show that industrial monitoring systems are only useful for improving operations and preventing faults if the data collected from machines and processes can be properly managed, understood, and used [7, [10], [15].

Advanced monitoring and control using digital twins plus cyber-physical synchronization is another new field in smart manufacturing research. In their investigation of cyber-physical systems' role in smart manufacturing, Tao et al. [12] outlined how digital twins—essentially digital representations of physical assets—can facilitate Industry 4.0-related tasks like monitoring, prediction, and optimization. By simulating equipment behavior, detecting problems, and improving system-level decision-making without disrupting real production processes, such technologies are particularly significant for industrial automation. Incorporating real-time sensing with virtual models to enhance visibility and predictive control, digital twin technology is a significant advancement in industrial monitoring [12].

II. SUGGESTED FRAMEWORK

A. SYMBOLIC LAYOUT

Industrial monitoring, safety alerts, conveyor motion, & pick-and-sort robotic operation are all integrated into the proposed system's ESP-based central controller. Industrial monitoring, robotic pick-and-sort, and Internet of Things communication are the three main functional units that make up the block diagram.

A thermal measurement device, voltage measurement device, and fire sensor are all connected to the ESP controller in the factory monitoring unit. In a continual fashion, these sensors record crucial machine and environmental variables. In order to prevent machinery or motors from overheating, a temperature sensor is installed. A voltage sensor may detect undervoltage or irregular variations by monitoring the power source or machine operating voltage. The industrial setup is protected from flames and other fire threats by the fire sensor. The ESP controller regularly gathers the sensor data and compares them to predetermined threshold levels. The controller will recognize an anomaly and start alert and safety procedures if any parameter goes over its threshold.

A robotic arm with servo motors for picking and placing objects onto a conveyor belt make up the robotic pick-and-sort unit. Conveyors transport items to the processing via sorting area, while robotic arms carry out pick-and-place operations in response to circumstances predetermined by programming or user input via the IoT platform. To retrieve items off a moving belt and deposit them in specified spots, the ESP controller synchronizes the movement of the conveyor and the angles of the servo motors. Industrial throughput is improved and human labor is reduced in sorting and packing jobs by this arrangement.

An LCD screen and a buzzer are part of the alert and output area. Details about the online interface, machine characteristics, Wi-Fi status, and system alarms are shown on the LCD. When dangerous situations like overheating, power loss, or fire detection occur, the buzzer immediately sounds an audible alarm. As an additional function, the buzzer may be set to indicate when robotic and sorting events have occurred.

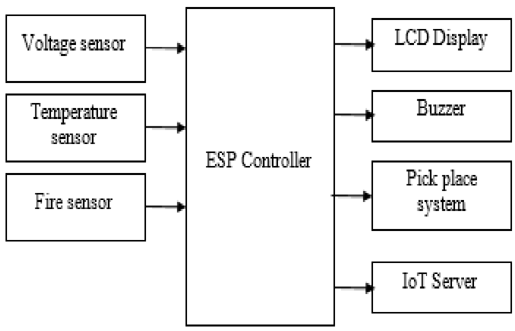

Fig. 1. System schematic for robotic pick-and-sort using industrial monitoring and a conveyor belt

The ESP device's Wi-Fi functionality is used to implement the IoT communication unit. To an Internet of Things (IoT) web server or dashboard, the controller sends current sensor data, warning states, and system status in real time. Conveyor and robotic control instructions may be sent back to the ESP over the same interface. The project flow outlines how the system may verify online buttons or remote instructions before adjusting the pick-and-place motors. Because of this, the platform may be used for remote operation as well as monitoring.

The following is the general idea of how it works. Following a Wi-Fi connection, the ESP controller will continually record readings from thermometers, voltage, and fire sensors. These values are shown locally and then sent to the Internet of Things server. The system notifies the user by buzzer and updates the online dashboard with the warning status whenever a fault situation is discovered. Conveyor and robotic operation web instructions are checked simultaneously by the controller. Object processing and placement are accomplished by driving the conveyor & servo motors in response to a pick-and-sort instruction. One integrated system that allows for real-time factory monitoring & automated material handling is made possible by this combination design.

B. FIRST VERSION OF HARDWARE

Modules for sensing, triggering, a display, and Internet of Things (IoT) interfaces were built into the hardware prototype of the suggested system, with an ESP controller serving as the primary processing and communication unit. This prototype shows how low-cost embedded technology may be used for industrial monitoring and pick-and-sort automation on conveyors.

At its very heart is the ESP controller. It operates the conveyor then robotic motors, connects with the Internet of Things server, receives data from industrial sensors, and conducts monitoring logic based on thresholds. With its built-in Wi-Fi, the ESP platform may run its own web dashboard or link up with another one, allowing for remote control and real-time viewing.

Machines and other industrial equipment may have their temperatures tracked with the use of a temperature sensor. Overloading the motor, running it continuously, or not having enough cooling may all lead to overheating, which this tool helps to detect. By monitoring the supply voltage or the machine's operating voltage, the voltage sensor allows the system to identify instances of unusually low voltage or unstable power. The fire sensor may detect flames or other fire dangers by positioning itself close to the monitored industrial area. When used in conjunction, sensors like these provide a fundamental but efficient layer for monitoring machine health and safety.

Objects are moved about the work area by use of the conveyor belt unit. Near the conveyor is a pick-and-place robotic system that is usually powered by servo motors. Using either human input or predetermined sorting logic, the robotic arm retrieves items from the conveyor & deposits them into certain bins or output sections. Through pre-programmed sequences of angular movement, the ESP controller controls the servo motors.

Local system information is shown on the LCD panel. Values from sensors, the state of the Wi-Fi connection, the web IP address, plus any alert messages are all shown. So that operators may check the system without accessing the online dashboard, the LCD can show live voltage, temperature, and fire status while it is operating. Whenever the system senses abnormal voltage circumstances, high temperatures, or fire, the buzzer activates as an alarm device.

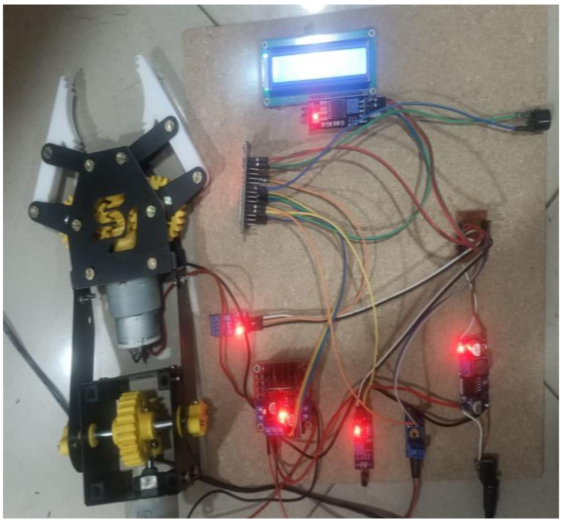

Fig.2. Robotic pick-and-sort system based on a conveyor belt and designed for use in an industrial setting

An Internet of Things (IoT) web interface for control and monitoring is also a part of the prototype. As well as uploading sensor readings & system performance to the online dashboard, the ESP also verifies the click of any web icons or instructions. The controller is able to operate the conveyor or spin the pick-and-place motors in response to a remote instruction. When operators in smart factories need to remotely monitor or manage industrial equipment, this function comes in quite handy.

Using small, inexpensive components, the created hardware prototype shows that the suggested industrial monitoring plus sorting system can automate material handling, provide remote access over the Internet of Things, and monitor machine safety.

III. DYNAMIC GRAPH

Industrial monitoring, Internet of Things connectivity, and robotic control based on conveyors are all laid out in the proposed system's flow diagram. Once the ESP controller is turned on, it initializes all of the sensors, LCD, buzzer, servo motor control pins, conveyor drive interface, and interface for the motors. After then, the controller will try to link up with any accessible Wi-Fi networks. After the connection is made, the user may monitor the system via the IoT interface by seeing the Internet Protocol or web information accessed on the LCD.

The ESP controller joins the primary control and monitoring loop after Wi-Fi startup. This loop is responsible for the system's constant readings of the temperature, voltage, and fire sensors. The data are shown on the LCD & sent through the IoT internet server so they may be monitored remotely. The controller then checks the values of all the sensors against a set threshold. The system will activate the buzzer and notify the web server of an overheating problem if the temperature goes beyond the threshold. A similar alert will be sent by the controller in the event that the measured voltage drops below the threshold, indicating an abnormal supply situation. The system quickly updates the online dashboard, triggers the buzzer, and considers the incident as a serious threat if the fire detector detects flame or fire.

In addition to keeping an eye on potential dangers, the controller also verifies the current state of any web-based instructions or buttons. In the absence of a web command, the system will keep updating the server and monitoring the industrial parameters. The electronic signal processor (ESP) starts the appropriate motors in response to web commands sent to the conveyors pick-and-place device. Once an item has been conveyed to the sorting point by the conveyor belt, it may be precisely picked and placed into its designated spot by use of the pick-and-place servo motors, which spin in accordance with the predetermined programming sequence.

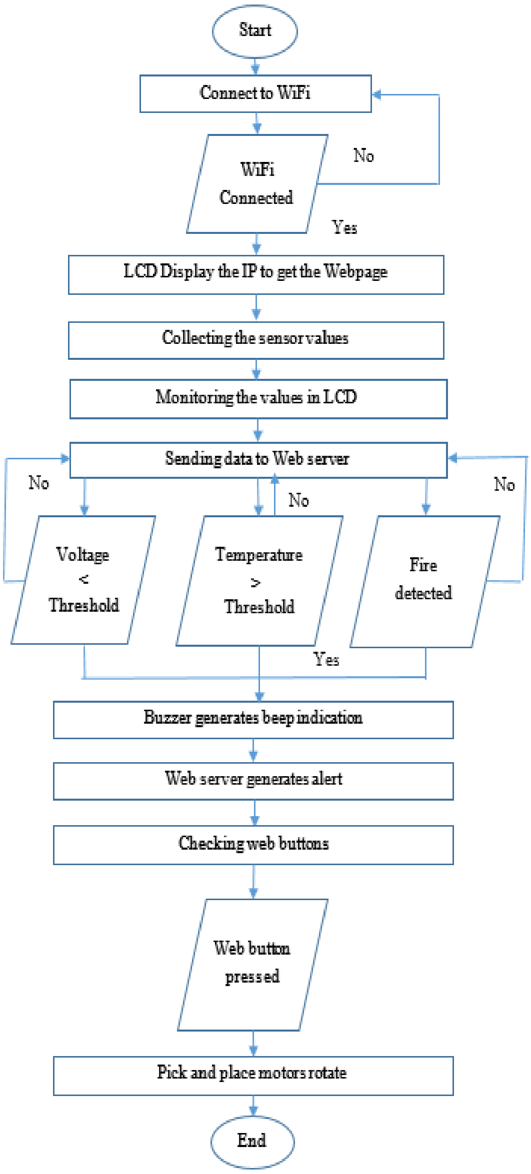

Fig. 3Schematic for a robotic pick-and-sort system that uses conveyor belts and is used in industrial monitoring

The smooth and coordinated operation of robotic material handling and industrial safety monitoring is guaranteed by this flow.

IV. INDUSTRY-RANDOM FINDINGS

As a hardware prototype, we put the proposed Internet of Things (IoT) industrial monitoring as well as conveyor belt-based pick-and-sort robotic system using an ESP device through its paces in a number of test cases to see how well it handled monitoring, fault detection, IoT communication, and robotic pick-and-sort. An ESP , a temperature and voltage sensors, a fire detector, an LCD screen, a buzzer, a conveyor belt mechanism, a robotic arm that picks and places objects using servos, and an

Internet of Things online monitoring interface made up the experimental setup. Experiments were conducted to see whether the system could detect hazardous operating situations, send out timely alarms, handle objects on conveyors under local or web-based management, and continually monitor industrial conditions.

The machine's temperature ranged from 29 to 33 degrees Celsius, the supply voltage was 11.8 to 12.3 volts, and the fire sensor readout showed no flame situation when the industrial surveillance section was running normally. At this point, the machine was deemed safe by the ESP controller; the buzzer was turned off; and, as shown in Figure 4, the LCD showed real-time data on voltage, temperature, and the status of the web connection. Depending on the state of the network, the IoT dashboard received updates with the same data every three to five seconds. Up until a web request / sorting request was sent, the robotic unit and conveyor stayed in standby mode as well. The system was able to reliably run in ongoing surveillance mode without false alarms, as proven by these findings.

Fig.4Displaying sensor data and monitoring status on an LCD

To ensure the temperature sensor could accurately record readings, it was subjected to very hot circumstances in close proximity to the industrial node. The temperature readings went up from the usual range to around 41°C to 46°C when the circumstances were out of the ordinary. In order to detect instances of overheating, the prototype used a threshold of 40°C. The ESP controller promptly signaled an improper machine temperature situation when a sensor's reading exceeded 40°C. The alarm went off, the screen showed a warning about the temperature being too high, and the status on the Internet of Things dashboard went from safe into warning. Repeated testing confirmed that the technology can provide a quick local warning for thermal irregularities in industrial equipment, with a latency of less than 1 s before threshold passing and buzzer activation.

By manipulating the input supply to mimic undervoltage situations, we were able to test the system's voltage monitoring capabilities. The output of the voltage sensor, when functioning normally, was around 12.0 V. The controller detected dangerously low voltage situations by progressively reducing the supply, with an upper limit of 10.5 V, throughout testing. The alarm was triggered, the buzzer was turned on, and the warning message was updated on the LCD the IoT dashboard as soon as the measured voltage fell within the range of 9.8 V-10.3 V. Because of the potential effects of a power outage on motor abilities, controller stability, and the dependability of production as a whole, the voltage alert plays a crucial role in industrial systems. Results from the trial proved that the monitoring node based on ESP can identify power outages and notify operators in time to prevent more harm.

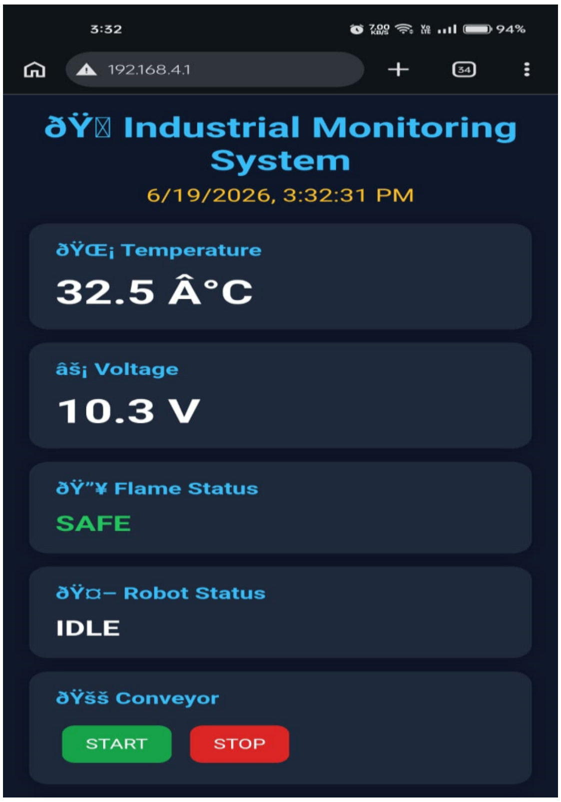

Fig.5. Web dashboard displays sensor information as well as status

In a controlled environment, the fire sensor was subjected to a flame source in order to verify its fire detecting mechanism. Normally, the output of the fire sensor would show that there was no fire. Immediate detection and classification of the fire event as a major hazard situation was achieved by the system upon introduction of flame near the sensor. A critical alert was shown on the IoT dashboard, the LCD flashed a fire warning signal, & the buzzer was switched on continually. It is appropriate for early danger indication in industrial situations, since the time to react of fire's detection stage was found to be roughly 0.5-1.0 s. This finding lends credence to the idea that the suggested system may double as a node to monitor machine health and simple fire protection measures.

Experiments were also conducted to verify the pick-and-place robotic operation and the conveyor belt. After placing a number of little items on a conveyor system, an online platform was used to initiate the pick-and-sort process. Pressing the relevant button on the web control sent a signal to the ESP controller, which in turn turned the servo motors in the predetermined order. After the item was conveyed to the select zone by the conveyor, it was selected and deposited into the specified area by the robotic arm. The pick-and-place mechanism finished one sorting cycle in around 4-6 seconds during repeated trials, with the exact time dependent on the item location and the route of the servo's rotation. It is possible to integrate industrial surveillance with basic robotics material handling in one integrated platform, since the movement stayed steady for lightweight test items.

To further investigate the system's behavior in a mixed monitoring and actuation environment, we also performed a failure and control scenario. During one typical test, the machine's temperature increased to 43°C when the conveyor pick-and-place instruction was running. With the completion of the pick-and-sort process, the system continued to show sensor readings, activate the buzzer, and transmit a temperature alert to the IoT dashboards. During a different test, the system triggered the voltage alarm even though the supply voltage decreased to 10.1 V while the robot was operating. This happened without breaking the monitoring loop. An essential feature of industrial automation systems, these findings demonstrate that the ESP controller can handle conveyor/robotic control duties and safety monitoring at the same time.

Fig.6. Automated Pick and Place features with web-based notification logging

During the course of the trials, we also monitored the IoT communication performance. The web platform received the remote control instructions for the robotic system without significant delay, and the sensor readings for temperature, voltage, the fire status have been posted successfully. Web buttons for robotic control usually responded within 1-2 seconds, depending on Wi-Fi connectivity, whereas the average interval for dashboard updates stayed at 3-5 seconds. This proves the system's viability for use in industrial monitoring and remote operator communication in real time.

Experiment findings support the practicality of the suggested platform for industrial automation. In typical operation, the system detected no fires, kept the temperature at 31 degrees Celsius, and kept the voltage around 12 volts. If there were any unusual circumstances, such as a temperature more than 40°C, a voltage lower than 10.5 V, or a fire, the alarm would go off. A web-based controller reliably controlled the pick-and-sort operation of the conveyor plus robotic arm, and an IoT dashboard showed the condition of the system in real-time. Smart assembly, safety in industry monitoring, integrated automated material handling may all benefit from the suggested ESP-based robotic sorting and industrial monitoring system, as these findings show. It's also practically cheap.

V. FINAL THOUGHTS AND PROSPECTS

A robotic system for picking and sorting items off a conveyor belt utilizing an ESP device and an Internet of Things (IoT) foundation was introduced in this article. A single smart manufacturing platform is created by the proposed system, which blends robotic automation based on conveyors with industrial parameter monitoring. The system integrates temperature and voltage sensors, fire detection, an alarm system that uses buzzers, an LCD display, communication over the Internet of Things dashboard, plus a motor-driven pick-and-place mechanism to increase material handling efficiency, decrease human effort, and improve industrial safety.A robotic system for picking and sorting items off a conveyor belt utilizing an ESP device and an Internet of Things (IoT) foundation was introduced in this article. A single smart manufacturing platform is created by the proposed system, which blends robotic automation based on conveyors with industrial parameter monitoring. The system integrates temperature and voltage sensors, fire detection, an alarm system that uses buzzers, an LCD display, communication over the Internet of Things dashboard, plus a motor-driven pick-and-place mechanism to increase material handling efficiency, decrease human effort, and improve industrial safety.

The built prototype proved that the ESP-based design can detect and react to abnormalities including excessive heat, undervoltage, and fire dangers in industrial machines in real time. Simultaneously, working under web-based control, the system effectively ran a robotic arm and conveyor belt through pick-and-sort operations. The platform is well-suited for smart factories, packing components, lines of manufacture, and warehouse automation, as the trial results shown that it can provide both local warnings and distant monitoring via the IoT interface.

This work has a lot of room to grow in the future. To accomplish more thorough machine health monitoring, additional sensors like vibration, current, gas, or load sensors may be incorporated. The pick-and-sort process may be enhanced using computer vision and object recognition algorithms to make it smarter and more adaptable. For use on a larger scale in industry, the robotic arm may be enhanced to accommodate multi-axis motion and a greater payload capacity. In order to make the system even better for Industry 4.0 applications plus large-scale smart manufacturing deployment, features including multi-node industrial networking, cloud intelligence, predictive maintenance models, and support for mobile apps are available.

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