IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 1, April 2026
Impact Factor: 8.2

Sparshpyroscope – Intelligent Thermal Detection

Chirag Meghani[1], Dhrumil Upadhyay[2], Krish Kankad[3],
Mr. Mitesh Parmar[4], Dr. Vipul Shah[5]
[123]B.Tech. Students, Department of Instrumentation and Control Engineering
Dharmsinh Desai University, Nadiad, Gujarat, India
Interns at Servilink Systems Limited, Vadodara, Gujarat, India
[4] Automation Engineer at Servilink Systems Ltd.
[5] Dean (FOT), Dharmsinh Desai University

Abstract: *Industrial systems have continuous operations, but at various electrical load and thermal load conditions. High temperature rise of panels, motors, cables or industrial equipment will result in insulation breakdown, relay tripping, fire and unexpected stoppage of production. Customary protection systems rely on current sensing and overload relays which do not sense localized heating or thermal abnormalities at an early stage.*

This article describes SparshPyroscope, a smart thermal surveillance scheme, which is a combination of Thermal camera, programmable logic controller (PLC) based decision rules, supervisory control and data acquisition (SCADA) of industrial equipment using a
temperature matrix profile generation from a low resolution infrared thermal sensor and checking the critical temperature values against the upper and lower threshold values. Based on this comparison, an automatic alarm and relay tripping action can be performed. More recently, PLC control and SCADA monitoring systems are integrated, which provide real-time monitoring and logging as well as remote access capabilities. This paper reviews the existing thermal monitoring technologies, PLC-based protection schemes, and SCADA integration capabilities. The report also discusses how clever thermal detection can improve reliability, safety and preventive maintenance in industrial applications..

Keywords: Thermal Imaging, PLC, SCADA, Industrial Safety, Temperature Monitoring, Relay Protection, Preventive Maintenance

I. INTRODUCTION

Electrical and control panels must run continuously and reliably in contemporary industrial settings. One of the main elements influencing the functionality and lifespan of electrical equipment is temperature rise. Insulation failure, fire risk, and expensive downtime can result from overheating in switchgear panels, motors, transformers, and cable joints.

Current, voltage, and overload conditions are the primary concerns of conventional protection systems. However, a lot of electrical problems start out as localized heating because of component deterioration, phase imbalance, or loose connections. Infrared thermal monitoring can identify these early thermal anomalies even though they might not show up in electrical parameters right away.

Thermal sensing in conjunction with programmable logic controllers (PLCs) and SCADA systems offers an intelligent and automated solution for equipment protection thanks to advancements in embedded systems and industrial automation. The development of thermal monitoring systems, PLC-based safety measures, SCADA integration methods, and the idea of SparshPyroscope as an intelligent thermal detection framework for industrial applications are all covered in this review paper.

DOI: 10.48175/IJARSCT-32376

II. LITERATURE REVIEW

The development of automation and embedded sensing technologies has led to a significant evolution in thermal monitoring and industrial protection systems. Electromechanical relays and manual inspection techniques were the primary components of earlier industrial protection systems. Relays for overcurrent and overload were frequently used to identify unusual electrical conditions. However, these systems were limited to electrical parameter monitoring and could not detect localized heating inside panels or equipment.

The application of infrared thermography for predictive maintenance in industrial settings has been investigated in a number of studies. Hot spots in transformers, motors, cable joints, and switchgear panels are frequently found using infrared cameras. These systems aid in early fault detection and enable non-contact temperature measurement. High-resolution thermal cameras, however, are frequently costly and are primarily utilized for sporadic inspections rather than ongoing surveillance.

Continuous thermal monitoring has become more feasible with the advent of inexpensive thermal sensor arrays. In order to identify anomalous conditions, researchers have proposed embedded thermal sensing systems that produce temperature matrices and examine maximum temperature values. By detecting temperature increases before they cause equipment failure, these systems increase safety.

PLC-based protection systems have also been widely used in industries for quick and accurate decision-making. PLCs are renowned for their deterministic execution, resilience, and fit for industrial settings. Research has shown that PLCs can be used for relay control, fault isolation, and overload protection. Nevertheless, the majority of PLC-based systems do not directly integrate thermal imaging data; instead, they rely on electrical signals.

By offering real-time visualization, alarm management, and historical data logging, SCADA systems further improve industrial monitoring. The significance of remote access to process variables and centralized supervision is emphasized by research in SCADA-based monitoring. System reliability is increased through automated control and data recording made possible by the integration of field devices with PLCs and SCADA.

Despite these developments, there exists a gap in combining low-cost thermal imaging, PLC-based intelligent decision logic, and SCADA-based monitoring into a unified protection framework. Many existing systems either focus only on thermal inspection or only on electrical protection. Therefore, an integrated approach that combines thermal matrix analysis, programmable control logic, and supervisory monitoring can provide improved preventive maintenance and equipment safety.

The concept of SparshPyroscope addresses this gap by integrating real-time thermal sensing with PLC-based threshold comparison and SCADA monitoring, forming a comprehensive industrial protection system.

III. VISION

In industrial environments, electrical panels and control systems operate continuously under varying load conditions. Components such as circuit breakers, contactors, busbars, cable terminals, and relays generate heat during operation. Under normal conditions, this heat remains within permissible limits. However, due to loose connections, phase imbalance, insulation degradation, overload, or environmental factors, abnormal temperature rise may occur.

Traditional protection systems are primarily designed to detect electrical faults such as overcurrent, short circuit, and voltage fluctuations. While these protections are essential, they do not always identify early-stage thermal abnormalities. In many cases, overheating begins gradually and may not immediately cause a significant change in current or voltage. As a result, faults may remain undetected until severe damage occurs.

Manual thermal inspection using handheld infrared cameras is commonly practiced in industries. Although effective, this approach has certain limitations. It depends on periodic inspection schedules and human observation. If a temperature anomaly develops between inspection intervals, it may go unnoticed. Moreover, continuous manual monitoring is not practical in large-scale industrial plants.

Intelligent thermal monitoring addresses these limitations by providing continuous and automated temperature supervision. By using thermal sensors to generate a temperature distribution matrix, it becomes possible to analyze the

DOI: 10.48175/IJARSCT-32376

ISSN
2581-9429
IJARSCT

entire monitored area instead of relying on single-point measurement. Extracting critical parameters such as maximum temperature, average temperature, or temperature gradient helps in identifying abnormal thermal behavior at an early stage.When thermal sensing is integrated with PLC-based logic, automatic decisionmaking can be implemented. The PLC compares real-time temperature values with predefined threshold limits and executes actions such as alarm generation or relay tripping. This reduces dependency on manual intervention and enhances system reliability.

Furthermore, integration with SCADA systems enables centralized monitoring, data logging, and trend analysis. Historical temperature data can be used for preventive maintenance planning and root cause analysis. Therefore, intelligent thermal monitoring combined with industrial automation forms an effective strategy for improving equipment safety, reducing downtime, and increasing operational efficiency.

IV. SYSTEM ARCHITECTURE OVERVIEW

The proposed SparshPyroscope system integrates thermal sensing, programmable control, relay protection, and supervisory monitoring into a unified industrial safety framework. The architecture is designed to provide real-time temperature monitoring, automated decision making, and centralized visualization.

The system begins with a thermal imaging sensor that captures the temperature distribution of the monitored equipment. The sensor generates a 32×24 temperature matrix representing spatial temperature variation across the target surface. This matrix is transmitted to the Programmable Logic Controller (PLC) for further processing.

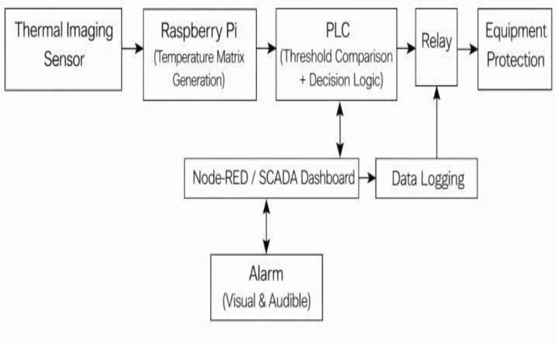


Fig.-1 System's Block Diagram

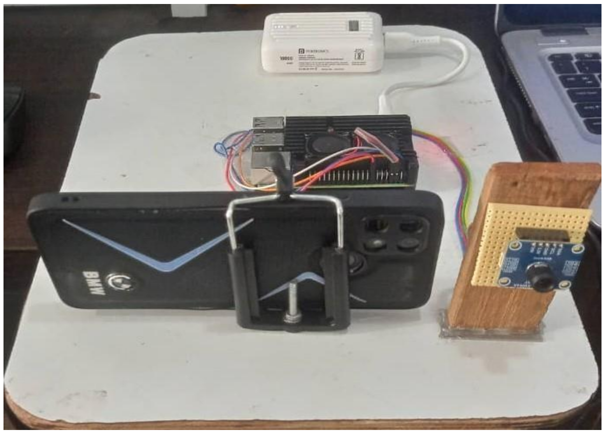


Fig.-2 System Setup

Inside the PLC, threshold comparison and decision logic are implemented. The PLC continuously evaluates the incoming temperature data and extracts critical parameters such as maximum temperature. These values are compared against predefined upper and lower threshold limits. If the temperature exceeds the upper limit or falls below the lower limit, appropriate control actions are triggered.

Based on the decision logic, the PLC generates relay control signals. The relay module acts as the final protection interface, disconnecting or isolating the equipment under abnormal thermal conditions. Simultaneously, alarm signals are activated to provide visual and audible alerts.

The system is further integrated with a SCADA platform through industrial communication over LAN. SCADA enables real-time monitoring, alarm visualization, and historical data logging. This integration ensures centralized supervision and improved preventive maintenance planning.

The PLC continuously compares temperature data with preset limits and identifies critical conditions. If thresholds are exceeded, it triggers relay actions to protect equipment and activates visual and audible alarms.

Fig.-3 PLC Setup

V. PERFORMANCE ANALYSIS

The performance of an intelligent thermal detection system depends on its response time, decision accuracy, reliability under varying industrial conditions, and integration efficiency with supervisory platforms. In the context of SparshPyroscope, system evaluation can be analyzed based on thermal sensing capability, PLC decision execution, relay response behavior, and SCADA-based monitoring effectiveness.

The thermal imaging sensor produces a 32×24 temperature matrix that represents the spatial heat distribution across the monitored surface. Unlike conventional single-point sensors, this matrixbased approach provides better fault localization and higher detection sensitivity. It allows the system to capture detailed temperature variations across different areas. By continuously extracting the maximum temperature value from the matrix, the system ensures that localized overheating is not overlooked. This capability greatly improves early-stage fault detection and enhances the reliability and safety of electrical panels and industrial equipment.

The processing stage plays a critical role in maintaining system accuracy. The Raspberry Pi processes the incoming thermal matrix and transfers the computed temperature parameters to the PLC. The PLC executes threshold comparison and decision logic within a deterministic scan cycle. Since PLCs operate with predictable execution timing, the system ensures consistent decision-making without delay. The response time of the control logic depends primarily on the PLC scan cycle and communication latency between modules. In industrial applications, this deterministic behavior is essential for reliable protection systems.

DOI: 10.48175/IJARSCT-32376

Fig.-4 Overall System Setup

Relay actuation performance is another important parameter in system evaluation. Once the temperature crosses predefined upper or lower thresholds, the PLC generates a control signal to the relay module. The relay isolates the equipment from the power source to prevent further damage. The delay between threshold violation and relay actuation is minimal due to direct hardware-level signaling. This rapid protective action enhances equipment safety and reduces the probability of catastrophic failures.

The integration of Node-RED and SCADA dashboard adds supervisory performance capabilities to the system. Real-time visualization ensures continuous monitoring of temperature values and alarm conditions. The implementation of graphical gauges and time-series plots improves operator awareness and supports preventive maintenance decisions. Data logging functionality allows historical trend analysis, which is essential for identifying recurring thermal patterns and gradual performance degradation.

System reliability is further strengthened through modular architecture. Each subsystem, including sensing, processing, decision-making, relay control, and visualization, operates independently but in coordination. This modular structure improves fault isolation and simplifies maintenance. Additionally, the use of industrial communication over LAN ensures stable data transmission between PLC and supervisory interface.

Overall, the evaluation indicates that the SparshPyroscope framework provides improved fault detection capability compared to traditional protection systems that rely solely on electrical parameters. The integration of thermal imaging with PLC-based logic and SCADA supervision results in enhanced safety, faster response, and better operational transparency in industrial environments.

VI. COMPARATIVE ANALYSIS

Stable real-time temperature acquisition, precise threshold detection, consistent relay response behavior, and dependable communication between sensing, control, and supervisory layers were all validated by experimental evaluation. Scalability and adaptability for industrial deployment are further supported by the modular design.

An industrial protection system's capacity to identify problems early on, react quickly to unusual circumstances, and offer ongoing monitoring support determines how effective it is. The main purposes of conventional electrical protection systems are to identify anomalies related to voltage, overcurrent, and short circuits. However, slow thermal accumulation brought on by loose connections, deteriorating insulation, phase imbalance, or aging components is the root cause of many industrial failures. These thermal anomalies frequently go unnoticed until serious harm is done.

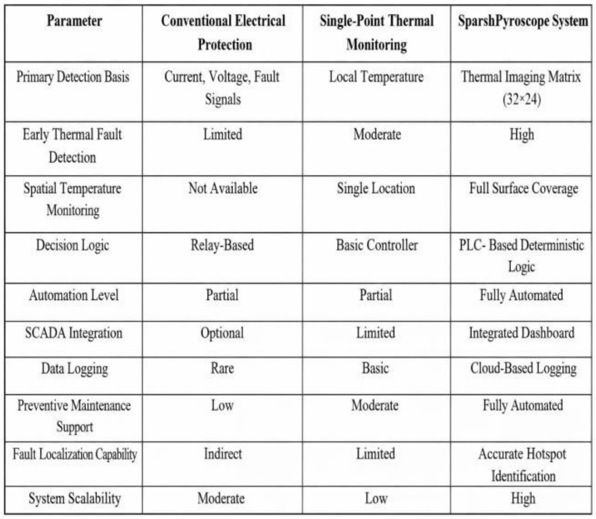
The SparshPyroscope framework extends thermal monitoring capabilities by employing a thermal imaging sensor that generates a 32×24 temperature matrix. This matrix-based approach enables spatial analysis of heat distribution across the monitored surface. Instead of relying on a single temperature value, the system evaluates distributed temperature patterns and extracts critical parameters such as maximum temperature and abnormal gradients.

In addition to improved sensing capability, the integration of programmable logic controller (PLC) based decision logic enhances deterministic control performance. The PLC executes threshold comparison within a fixed scan cycle, ensuring reliable and predictable protective action. The relay module provides immediate isolation of equipment under unsafe conditions, thereby reducing the risk of severe damage.

The incorporation of Node-RED based SCADA dashboard further differentiates the system from traditional protection schemes. Real-time visualization, alarm status indication, and cloudbased data logging enable historical trend analysis and preventive maintenance planning. This integrated architecture significantly improves operational transparency and safety.

A structured comparison between conventional systems and the proposed SparshPyroscope framework is presented in Table 1

Table 1. Comparison of Thermal Monitoring Approaches



Parameter	Conventional Electrical Protection	Single-Point Thermal Monitoring	SparshPyroscope System
Primary Detection Basis	Current, Voltage, Fault Signals	Local Temperature	Thermal Imaging Matrix (32×24)
Early Thermal Fault Detection	Limited	Moderate	High
Spatial Temperature Monitoring	Not Available	Single Location	Full Surface Coverage
Decision Logic	Relay-Based	Basic Controller	PLC- Based Deterministic Logic
Automation Level	Partial	Partial	Fully Automated
SCADA Integration	Optional	Limited	Integrated Dashboard
Data Logging	Rare	Basic	Cloud-Based Logging
Preventive Maintenance Support	Low	Moderate	Fully Automated
Fault Localization Capability	Indirect	Limited	Accurate Hotspot Identification
System Scalability	Moderate	Low	High

The comparative evaluation demonstrates that the SparshPyroscope architecture provides superior thermal fault detection capability compared to conventional electrical protection systems and single-point thermal monitoring approaches. The combination of spatial temperature sensing, deterministic PLC-based control, and real-time supervisory monitoring significantly enhances system reliability and safety. This integrated approach supports predictive maintenance strategies and reduces the probability of unexpected industrial downtime.

VII. CHALLENGES AND EXECUTION

The practical implementation of an intelligent thermal detection system in industrial environments involves several technical and operational challenges. Although the SparshPyroscope framework integrates thermal imaging, PLC-based logic, relay protection, and

SCADA visualization into a unified architecture, careful system design and calibration are essential to ensure reliable performance under real industrial conditions.

7.1 Sensor Accuracy and Calibration

Thermal imaging sensors such as low-cost infrared arrays are sensitive to environmental factors including ambient temperature, airflow, humidity, and surface emissivity. Variations in emissivity between metallic and insulated surfaces can affect temperature readings. Therefore, proper calibration is required to minimize measurement errors. Periodic validation against reference temperature instruments improves reliability and ensures consistent detection accuracy. Additionally, mounting position and field of view significantly influence the quality of thermal data. The sensor must

DOI: 10.48175/IJARSCT-32376

be installed at an optimal distance to capture the complete monitoring area without distortion. Improper placement may result in incomplete surface coverage or false hotspot detection.

7.2 PLC Scan Time and Deterministic Response

The PLC executes threshold comparison and decision logic within its scan cycle. In high-speed industrial systems, response time becomes critical. The scan time must be optimized to ensure rapid relay activation when abnormal temperature conditions are detected. Excessively long scan cycles may delay tripping signals, whereas extremely short scan cycles may increase processor load. Therefore, balancing deterministic control performance with processing efficiency is necessary. Structured ladder logic and efficient threshold comparison algorithms help reduce computational overhead.

7.3 Threshold Selection and False Alarms

Defining appropriate upper and lower temperature thresholds is a key implementation consideration. If thresholds are set too low, frequent false alarms may occur due to minor temperature fluctuations. Conversely, if thresholds are set too high, early-stage faults may remain undetected. Adaptive threshold configuration based on equipment rating, historical temperature trends, and environmental conditions enhances system reliability. Integrating hysteresis logic within PLC programming further reduces oscillation-based false triggering.

7.4 Communication Reliability and Network

Latency

The SparshPyroscope system relies on LANbased communication between the PLC and SCADA dashboard. Network stability plays a crucial role in real-time data visualization and logging. Packet loss, latency, or network congestion may temporarily affect monitoring continuity. To mitigate such issues, buffering techniques and periodic heartbeat signals can be implemented to verify communication integrity. Local PLC-level protection ensures that even if SCADA communication fails, relay-based equipment protection remains active.

7.5 Data Logging and Storage Management

Continuous temperature monitoring generates large volumes of data. Efficient storage mechanisms are required to maintain historical records without excessive memory usage. Cloudbased logging solutions, such as integration with structured databases or spreadsheet-based storage, must be optimized to prevent redundant data accumulation. Filtering algorithms can be used to store only significant events, such as threshold crossings or abnormal trend deviations.
This approach improves long-term maintainability and simplifies predictive maintenance.
Additionally, data compression techniques can be applied to further reduce storage requirements without losing critical information. Proper data management also enhances system performance and ensures faster access to important records when needed.

7.6 System Scalability

Industrial facilities often require monitoring of multiple panels or distributed equipment. The architecture must support expansion without major redesign. The modular design of the SparshPyroscope system allows multiple thermal nodes to be integrated into a centralized SCADA platform. However, as the number of monitored points increases, communication bandwidth and PLC memory allocation must be carefully managed. Scalable architecture planning ensures long-term adaptability.

7.7 Industrial Safety and Compliance

Any protection system installed in industrial environments must comply with electrical safety standards and operational guidelines. Proper isolation between sensing modules, control circuits, and high-voltage equipment is

DOI: 10.48175/IJARSCT-32376

mandatory. Relay modules must be rated according to load specifications, and alarm devices must meet industrial signaling standards. Careful hardware selection and proper grounding practices reduce the risk of electrical interference and enhance operational safety.

VIII. EXPERIMENTAL EVALUATION

The SparshPyroscope system was experimentally validated to evaluate its sensing accuracy, decision logic performance, and supervisory monitoring capability. The setup included a thermal imaging sensor generating a 32×24 temperature matrix, a PLC executing threshold comparison logic, relay-based protection, and a
Node-RED dashboard for real-time visualization.

During testing, the system accurately tracked temperature variations and updated live readings on the dashboard without noticeable delay. When the measured temperature exceeded predefined threshold limits, the PLC successfully triggered relay tripping and activated alarm indications. The response was consistent and repeatable, confirming deterministic PLC execution.

Alarm visualization on the dashboard changed instantly from normal to active state during abnormal conditions. Reset functionality was verified to restore normal monitoring once temperature returned within safe limits.

Data logging was also validated, enabling storage of timestamped temperature values for trend analysis. Continuous operation testing showed stable communication between sensing, control, and dashboard layers without system interruption. The experimental evaluation confirms that the SparshPyroscope framework provides reliable real-time thermal monitoring, automated protection, and supervisory control suitable for industrial applications.

IX. CONCLUSION

The conceptual framework and implementation overview of SparshPyroscope, an intelligent thermal detection system intended for industrial overheating monitoring and protection, were presented in this paper. The suggested architecture combines relay-based protective isolation, SCADA-enabled supervisory monitoring, matrixbased thermal imaging, and programmable logic controller (PLC) decision logic into a single, modular system.

The suggested method uses a 32x24 infrared sensing matrix to introduce spatial thermal analysis, in contrast to traditional protection systems that mainly rely on electrical parameters. This makes it possible to identify abnormal heat distribution patterns and localized hotspots early on, which may not be possible with conventional current or voltage-based protection techniques. Under hazardous circumstances, the PLC's deterministic execution capability guarantees accurate threshold comparison and prompt protective relay activation.

By offering real-time visualization, alarm indication, and historical data logging, the integration of Node-RED based dashboard monitoring improves system transparency. Preventive maintenance planning, operational awareness, and fault detection capabilities are all enhanced by this layered architecture.

Stable real-time temperature acquisition, precise threshold detection, consistent relay response behavior, and dependable communication between sensing, control, and supervisory layers were all validated by experimental evaluation. Scalability and adaptability for industrial deployment are further supported by the modular design.

All things considered, the SparshPyroscope framework shows a successful strategy for intelligent, automated, and predictive thermal monitoring in industrial settings. The system enhances operational reliability, decreases downtime, and improves equipment safety by integrating thermal sensing with deterministic control and supervisory visualization.

X. FUTURE SCOPE

Enhancement of thermal sensing capability through integration of higher resolution infrared arrays to improve hotspot detection accuracy and spatial analysis precision.

Implementation of machine learning algorithms for predictive fault detection based on temperature trend analysis and anomaly identification.

DOI: 10.48175/IJARSCT-32376

Expansion of cloud-based IoT connectivity to enable centralized monitoring of multiple industrial panels across distributed locations.

Development of a dedicated mobile application for real-time alerts, remote supervision, and system status notifications.

Integration with advanced industrial communication protocols such as Modbus

TCP/IP and OPC-UA to improve interoperability with Industry 4.0 systems.

Implementation of intelligent data analytics for automatic maintenance scheduling and predictive equipment health assessment.

Incorporation of automated selfcalibration techniques to improve longterm sensing stability and reduce measurement drift.

Deployment of scalable multi-node architecture for monitoring large industrial plants with centralized supervisory control.

REFERENCES

[1]. 7Semi, “MLX90640 Thermal Camera Sensor – 32×24 IR Array,” 7Semi Electronics Pvt. Ltd. Available: https://www.7semi.com
[2]. Melexis Microelectronics, “MLX90640 32x24 IR array high resolution thermal camera,” Datasheet, 2019.
[3]. F. P. Incropera and D. P. DeWitt, Fundamentals of Heat and Mass Transfer, 7th ed.,Wiley, 2011.
[4]. Rockwell Automation, “MicroLogix 1100 Programmable Controllers User Manual,” Allen-Bradley Publication, 2016.
[5]. Rockwell Automation, “FactoryTalk View Site Edition User Guide,” Rockwell Automation Documentation, 2018.
[6]. N. Mahalik, Industrial Automation and Process Control, McGraw-Hill Education, 2003.
[7]. H. Boyes, B. Hallaq, J. Cunningham, and T.Watson, “The industrial internet of things (IIoT): An analysis framework,” Computers in Industry, vol. 101, pp. 1–12, 2018.
[8]. S. Yin, X. Li, H. Gao, and O. Kaynak, “Data-based techniques focused on modern industry: An overview,” IEEE Transactions on Industrial Electronics, vol. 62, no. 1, pp. 657–667, 2015.
[9]. Kusiak and M. Verma, “Monitoring and fault detection in industrial processes,” Journal of Manufacturing Systems, vol. 30, no. 2, pp. 73–79, 2011.
[10]. Node-RED Foundation, “Node-RED Documentation,”

DOI: 10.48175/IJARSCT-32376