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Design and Implementation of a Smart Quality Control System for Relay Manufacturing using IoT and Intelligent Inspection Techniques

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ABSTRACT: Relay-based switching systems are vital components used across various sectors such as automotive, electrical, and industrial systems. These components must operate with high reliability and accuracy to ensure the overall system's performance. However, achieving consistent product quality in relay manufacturing poses a significant challenge due to variations in manual inspection methods and inconsistencies in traditional testing processes.

This paper introduces a Smart Quality Control System (SQCS) designed specifically for relay manufacturing. The SQCS utilizes real-time sensors, IoT-enabled microcontrollers, and vision-based inspection techniques to monitor and evaluate critical relay parameters like contact resistance, coil inductance, bounce characteristics, and surface anomalies. It incorporates cloud-based data handling using MQTT protocol for real-time monitoring, remote access, and data analytics. The experimental implementation of this system demonstrated notable improvements in defect detection accuracy, production efficiency, and traceability.

KEYWORDS: Relay Quality Control, Contact Resistance, IoT in Manufacturing, Defect Detection, Coil Testing, Predictive Maintenance, Smart Factory, Vision-Based Inspection, MQTT, CAN Bus.

I. INTRODUCTION

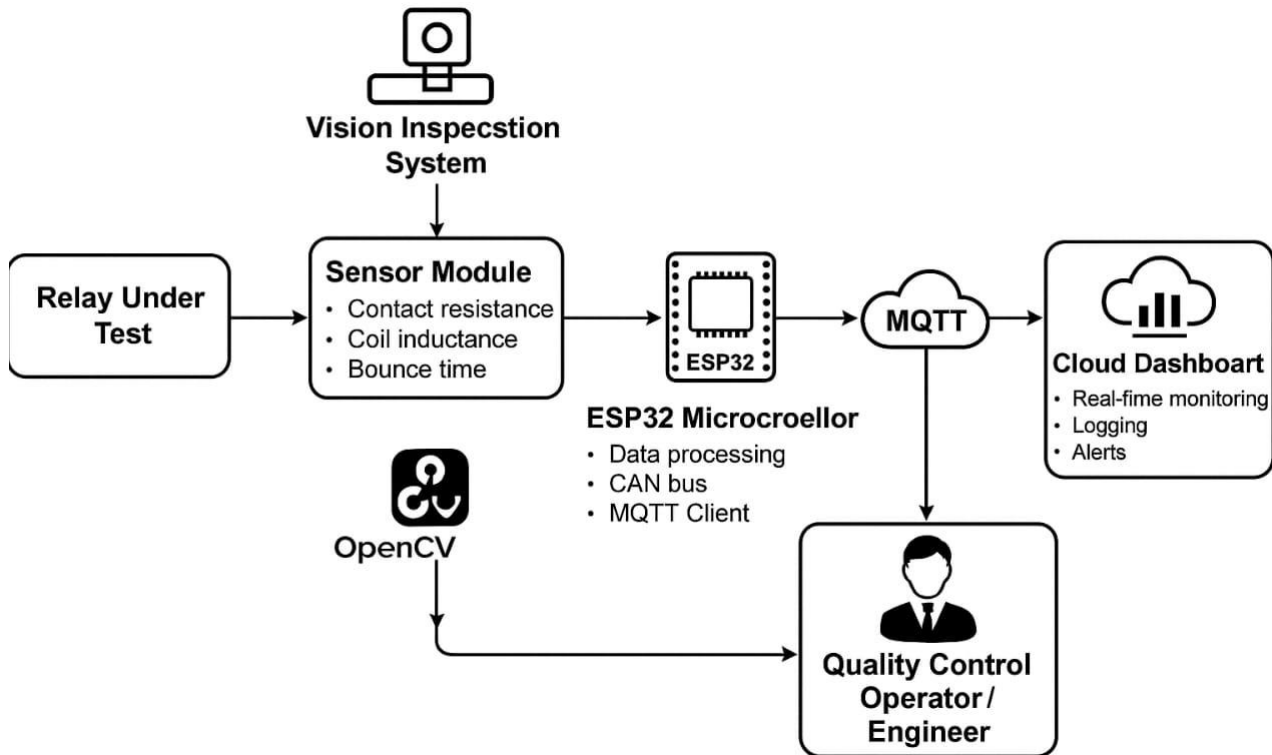
Relays play a fundamental role in various control and safety systems due to their ability to isolate and control high-current circuits with low-power signals. Their use is prevalent in applications ranging from household appliances to complex automotive and industrial systems. Given their importance, ensuring the quality and reliability of relays during production is critical.

Traditionally, relay quality control relies heavily on manual inspection and semi-automated systems. These approaches are not only labor-intensive but also susceptible to human error, inconsistent results, and delays, especially in high-volume manufacturing environments. Moreover, conventional testing setups often lack the ability to collect and analyze data in real-time, making predictive maintenance and continuous improvement challenging.

With the rise of Industry 4.0, integrating Internet of Things (IoT) technologies and intelligent inspection systems into manufacturing processes has become a promising solution. These technologies offer real-time data acquisition, remote monitoring, predictive analytics, and automated quality assessments. In this research, we propose a Smart Quality Control System (SQCS) that combines sensor-based testing, machine vision, IoT-based communication, and cloud analytics to enhance the accuracy, speed, and traceability of relay inspection processes.

This project not only addresses the limitations of conventional systems but also demonstrates a practical and scalable solution that aligns with modern smart factory requirements.

Workflow of Smart Quality Control System (SQCS)



II. LITERATURE SURVEY

Previous research in relay inspection has primarily focused on manual methods or partially automated systems. Patil et al. developed a basic test bench for coil and contact resistance measurements, but it lacked communication and data logging capabilities. Shinde introduced a more advanced relay sorting method, but it did not support cloud integration or real-time monitoring.

Modern platforms like Blynk and ThingSpeak have enabled scalable IoT dashboards, though limited by hardware constraints in low-power microcontrollers. Investigations using ESP32 and STM32 microcontrollers have demonstrated the feasibility of implementing CAN bus communication and MQTT protocols, which are essential for industrial environments.

Vision inspection technologies, particularly those using OpenCV, have shown promise in electronics inspection. However, their application in relay manufacturing remains underutilized. Our system aims to bridge this gap by combining these technologies in a cohesive quality control framework.

III. METHODOLOGY

The methodology adopted for designing the Smart Quality Control System (SQCS) involves a systematic integration of hardware, software, and data analytics components. The process can be broken down into the following phases:

Problem Analysis and Requirements Definition

A detailed study of existing relay testing procedures was conducted to identify limitations such as manual errors, lack of real-time monitoring, and poor traceability. Key quality parameters—contact resistance, coil inductance, bounce time, and visual defects—were selected for automation.

Hardware Selection and Setup

Precision sensors were chosen for electrical parameter measurement, while high-resolution cameras were integrated for vision-based inspections. An ESP32 microcontroller was selected due to its dual-core processing, in-built Wi-Fi, CAN protocol support, and compatibility with MQTT for cloud communication.

Software Development and Vision System

Custom firmware was developed to read sensor data and perform preprocessing before transmission. OpenCV libraries were used for developing computer vision algorithms to detect misalignment, surface irregularities, and sealing issues.

IoT Integration and Cloud Connectivity

The MQTT protocol was used for efficient data transmission to a cloud-based dashboard. The dashboard was designed for real-time monitoring, historical data analysis, and report generation.

Pilot Deployment and Testing

The complete system was deployed on a test relay production line. Data from various stages was collected, analyzed, and compared against conventional methods to evaluate the system's effectiveness.

Performance Evaluation

Metrics such as defect detection accuracy, scrap rate reduction, operator error, and system uptime were monitored

IV. CONCLUSION

This study successfully demonstrates the development and deployment of a Smart Quality Control System tailored for relay manufacturing. By combining sensor-based inspection, machine vision, IoT communication, and cloud analytics, the system improves product quality, reduces scrap, and enhances production efficiency.

Its modular, scalable design ensures compatibility with existing manufacturing setups, promoting seamless adoption. Future improvements may include AI-driven decision-making, mobile application support, and ERP integration for full-process automation.

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