Automatic Continuity and Resistance Testing of 20A Rotary CAM Switch

Abhijit V Lohakane[1], Om W Khandale[2], Kunal C Mahajan[3], Hrutik S Kanade[4], Priti Choudhari[5]
[1]*Project Manager Rishabh Instrument Nashik, India*
[2,3,4]*Dept. of EnTC, MET Institute of Engineering Nashik, India*
[5]*Assistant Professor Dept. of EnTC, MET Institute of Engineering Nashik, India*

***Abstract*—This study focuses on the creation of an automated solution for testing continuity and resistance in rotary cam switches by leveraging Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) systems. Manual testing processes are often inefficient, inconsistent, and susceptible to human error, which can hinder product quality and slow down production lines. The proposed system automates the testing procedure, ensuring reliable, precise, and rapid measurements. A four-wire resistance testing method is implemented to reduce inaccuracies caused by contact and lead resistances, thereby increasing overall accuracy. The integration of SCADA facilitates live system monitoring, automatic data recording, and report generation, significantly improving quality assurance practices. This work highlights a step forward in industrial automation by enhancing the precision, dependability, and scalability of switch testing operations.**

***Index Terms*—PLC, SCADA, Automation, Rotary Cam Switch, Continuity Testing, Resistance Measurement, Four Wire Resistance Testing Method.**

I. INTRODUCTION

Rotary cam switches play a vital role in electrical systems by enabling or interrupting electrical circuits. Their performance and reliability must be thoroughly tested, particularly for continuity and resistance, to ensure they meet operational standards under diverse conditions.

Despite their importance, many industries still rely on manual testing methods, which present several drawbacks. These include time-consuming procedures, dependence on skilled operators, and vulnerability to human error. Such challenges often lead to inconsistent testing results, compromising product reliability and customer satisfaction. Furthermore, manual processes lack the ability to scale efficiently, falling short of the requirements of modern automated industrial environments where precision and high throughput are essential.

The motivation behind this research arises from the need to overcome these inefficiencies through automation. By introducing automated testing, it becomes possible to improve testing precision, enhance efficiency, and maintain a high standard of product consistency. This study is dedicated to developing a dependable and automated solution for evaluating rotary cam switches.

Conventional methods suffer from limitations in speed, accuracy, and repeatability. Manual testing not only introduces variability due to operator handling but also increases the risk of errors in documentation and reporting. These shortcomings hinder the ability of industries to meet rising demands and strict quality control requirements.

To resolve these issues, there is a pressing need for a system that delivers high accuracy and repeatability with minimal human involvement. Developing such a system is crucial for maintaining consistent quality assurance in rotary cam switch production.

The main goal of this research is to design and implement an automated continuity and resistance testing system for rotary cam switches, with the following objectives:

1. Minimize human-induced errors and variability in test results.
2. Reduce overall testing time while preserving high accuracy.
3. Provide scalability to support growing production needs.
4. Enable real-time monitoring, automated data collection, and report generation to enhance quality control processes.

This work introduces an innovative testing system that com- bines Programmable Logic Controllers (PLC) and Supervisory Control and Data Acquisition (SCADA) for optimal performance. The system employs the Kelvin (four-wire) resistance measurement method to reduce the impact of lead and con- tact resistance, thereby improving accuracy. Key components include stepper motors for accurate rotational positioning, pneumatic actuators for secure component placement, and an intuitive SCADA interface for real-time observation and automated documentation.

By addressing the shortcomings of manual testing, the proposed solution offers a more efficient, precise, and scalable approach, aligning with the demands of modern industrial automation. This system significantly boosts operational efficiency and product reliability, making it a valuable asset in quality assurance and production environments.

II. LITERATURE REVIEW

[1] Contact Resistance Measurement Techniques for Electrical Switches and Connectors (Holm, 2000)
Holm investigated the factors influencing contact resistance, such as oxide build-up, contaminants, and contact geometry. The study revealed that resistance increases with surface degradation, especially in high-contact environments, and highlighted the necessity of regular, precise resistance testing to maintain operational reliability in electrical switches. Relevance: This research forms the theoretical basis for accurate resistance measurement, a key focus of this project.

[2] Continuity Testing in Multi-Contact Systems: Automation and Accuracy Improvements (Zhang et al., 2015)
Zhang and colleagues developed an automated continuity testing system for multi-contact devices using microcontroller- based solutions. Their system significantly reduced manual effort, improved testing speed, and minimized human error, ensuring consistency and early fault detection. Relevance: This work supports the goal of automating continuity testing for rotary CAM switches, ensuring greater accuracy and operational efficiency.

[3] Advances in CAM Switch Applications and Reliability (Kimura and Sato, 2017)
Kimura and Sato reviewed the reliability of CAM switches in industrial environments, noting frequent contact degradation in high-demand applications. Their findings highlighted the need for regular automated testing to monitor switch health and maintain performance. Relevance: This study underscores the necessity of automated solutions to ensure the consistent reliability of CAM switches in industrial settings.

[4] Automated Testing Solutions for Electrical Contact Resistance (Patel et al., 2018)
Patel's research compared manual and automated testing approaches, showcasing the superiority of automation in terms of speed, consistency, and detection accuracy. The study highlighted the benefits of programmable testing devices for enhancing reliability. Relevance: This research aligns with the project's aim to enhance testing efficiency and accuracy through automation.

[5] Kelvin 4-Wire Testing Method
The Kelvin 4-wire testing method is a widely adopted technique for measuring low-resistance values with high precision.Unlike traditional 2-wire methods, this approach uses separate pairs of wires for current supply and voltage measurement, eliminating the influence of lead resistance on the measurement. This technique is ideal for ensuring accurate

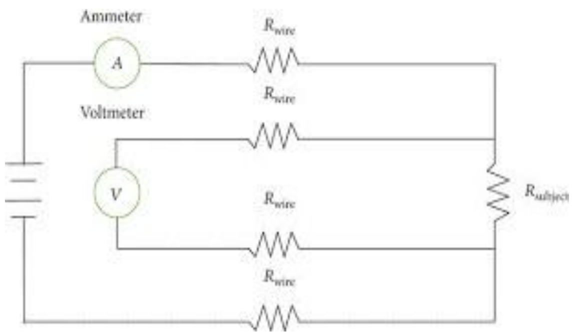

Fig. 1. Kelvin Test Method

resistance readings in applications requiring low-resistance testing, such as rotary CAM switches.

III. METHODOLOGY

This section details the automated testing system's development methodology using PLC and SCADA technologies to enhance the efficiency and accuracy of continuity and resistance measurements in rotary cam switches.

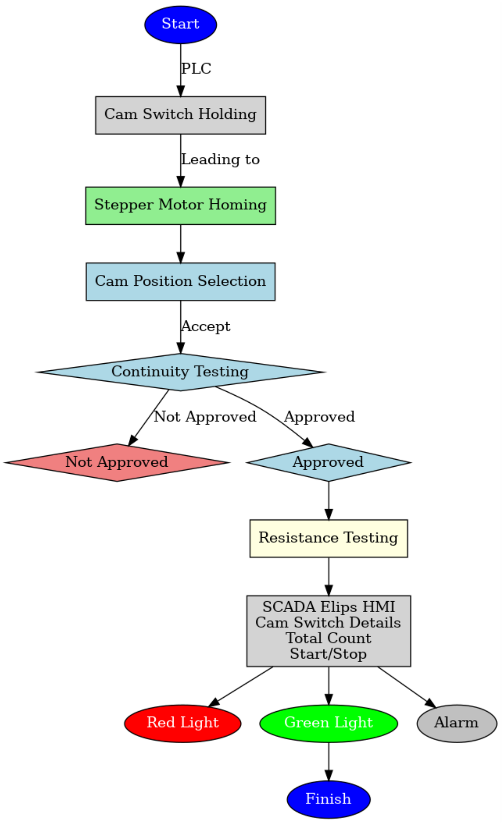

Fig. 2. System Work Flow

1) Start Process: Cam switch positioning and holding.
2) Stepper Motor Homing: Ensuring correct position before testing.
3) Continuity Testing: Measurement of closed contacts.
4) Resistance Testing: Utilizing four-wire measurement for precision.
5) Decision Making: Approval or rejection based on thresh- olds.
6) Report Generation: Automated documentation through SCADA HMI.

IV. MECHANICAL DISIGN

The automation of switch testing, particularly for CAM switches, plays a crucial role in industrial settings where reliability, precision, and speed are key. In our project, the mechanical assembly serves as the foundation for automated continuity and resistance testing. This section will detail the mechanical structure, design choices, and the functions of the four pneumatic cylinders, the motorized knob holder, and probe insertion system. Furthermore, we will highlight the key testing methods, the role of sensors, and the integration of Mitsubishi PLC and SCADA for smooth operations.

Purpose and Design Requirements:

The primary goal of this mechanical assembly is to automate the testing of CAM switches by incorporating automation technologies such as pneumatic cylinders and motors, while integrating these components with advanced control systems. Testing involves both continuity and resistance checks, which ensures the functional integrity of each CAM switch. For this project, the mechanical system must provide:

- Precise rotation of the CAM switch knob.
- Proper alignment and insertion of test probes.
- Secure holding and positioning of the switch during tests.
- Seamless interaction between the mechanical components, PLC system, and SCADA interface.

Overview of Mechanical Components

This automated testing system includes four critical pneumatic cylinders, a motorized knob holder, and a system for inserting probes to carry out continuity and resistance testing. Below are the detailed descriptions and functions of each component:

1) Pneumatic Cylinders:
   - Top Cylinder: o Function: The top cylinder is responsible for holding the CAM switch firmly in place during the entire testing process.
     Operation: It moves vertically, applying pressure to ensure the switch does not move while the testing probes are inserted, and while the knob is being rotated. This stability is essential for obtaining accurate test results.

   - Bottom Cylinder: o Function: This cylinder operates the motorized knob holder. The knob holder rotates the CAM switch at pre-defined angles necessary for testing different switch positions.

   - Side Cylinders (Left and Right): o Function: These two cylinders are responsible for inserting the continuity and resistance testing probes into the CAM switch.
     Operation: The cylinders move laterally, inserting probes at precise locations on the switch contacts. Once the testing is complete, they retract the probes, allowing the system to advance to the next step.

2) Knob Holder and Motor: The motor shown in fig 11 and the knob holder shown in fig 22 are an integral part of the test setup because they directly make a contact with the knob of the switch and position of the knob and its testing depends upon the precision of the knob holding and motor rotation.

Rotation Accuracy: The motor provides exact control over the angular rotation of the switch. This is critical for ensuring that the CAM switch is tested across all its possible states, with measurements being taken at each step.

Integration with PLC: The motor receives commands from the Mitsubishi PLC, which controls the rotation speed and angle. This integration allows for seamless transitions between testing stages.

3) Sensor Integration

Sensors are essential for ensuring that all components function together seamlessly. The following key operations rely on sensor feedback:

- Total Number of reed sensors used in the system is 4
- Each Cylinder carries one reed sensor to detect the position of the cylinder.
- There is a proximity sensor fixed on the motor holder so that the position of the motor is known.
- Each sensor acts as an individual output and receives individual feedback from the PLC.

V. RESULTS AND DISCUSSION

Continuity testing result:

Switches exhibit different continuity states depending on their positions. In a SCADA system, reference data for each switch, including its expected continuity parameters at various positions, is preconfigured. During operation, the actual continuity status of the switch is monitored and compared against these predefined reference values. If the real-time continuity aligns with the reference parameters stored in the SCADA system, the switch is deemed to be functioning correctly. However, if a discrepancy is detected between the expected and actual continuity states, it indicates a potential fault or malfunction in the switch, necessitating further inspection or corrective action.

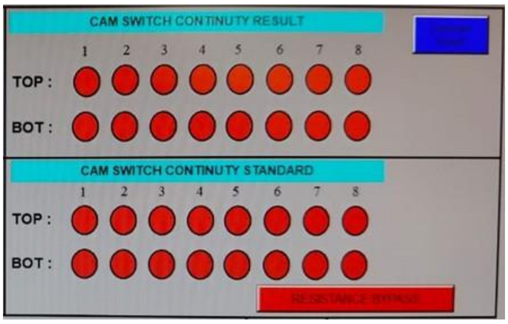

Fig. 3. (a)

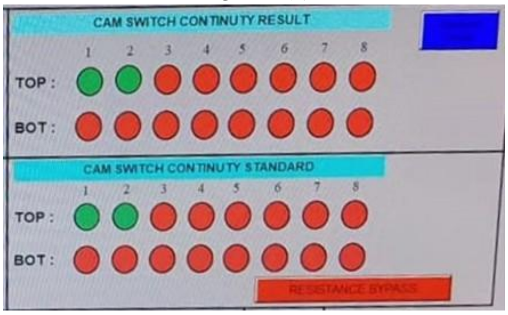

Fig. 4. (b)

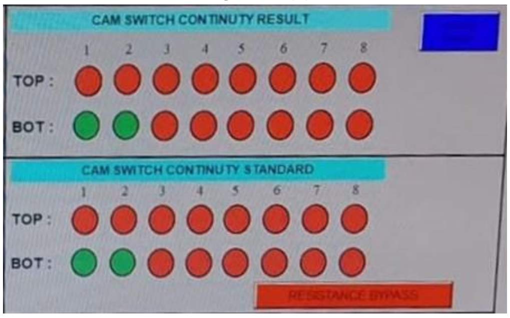

Fig. 5. (c)

Cam switch continuity result with standard value.

Following the successful completion of the continuity test, the system proceeds to assess the resistance of the switch.

Resistance testing result:

A controlled 1A test current is applied to the input terminals, and an integrated precision multimeter measures the resistance across the switch contacts. The obtained resistance value is then compared against a predefined threshold. If the measured resistance exceeds the acceptable limit (e.g., 5 mOhm), the testing process is immediately halted, and a failure condition is triggered. A buzzer and red LED indicator activate to alert the operator of the defect.

Conversely, if the resistance falls within the permissible range, the system automatically transitions to testing the switch in other positions. This fully automated testing protocol ensures comprehensive validation of each switch, enhancing both accuracy and operational efficiency

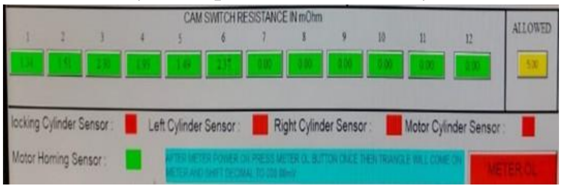

Fig. 6. contact resistance below allowed value

This is the values of contact resistance of each contact of 20 A 3P 2W 90D Changeover CAM switch, it is a 3 stack CAM switch. Resistance value of 1st contact has 1.34, 2nd contact has 1.51, 3rd contact has 2.30, 4th contact has 1.93, 5th contact has 1.49, 6th contach has 2.37.

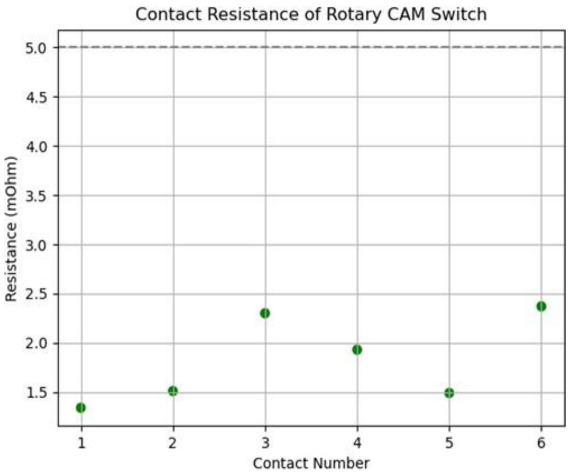

Fig. 7. contact Resistance bellowed value

The presented graph illustrates the contact resistance mea- surements of a 20 A, 3P, 2W, 90D Changeover CAM switch. The X-axis represents individual switch contacts, while the Y- axis denotes resistance values in milliohms (mOhm). The mea- sured resistance values for each contact are consistently below the predefined threshold of 5 mOhm, as indicated by green dots. This confirms that the switch is functioning optimally within acceptable limits. The automated system processes the acquired data, validates compliance with operational standards, and triggers a notification for report generation, confirming the CAM switch's proper functionality.

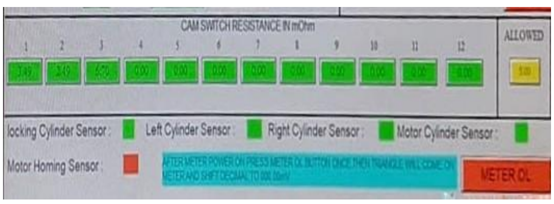

Fig. 8. contact resistance above allowed value

This is the values of contact resistance of each contact of 20 A 2P 2W Changeover CAM switch, it is a 2 stack CAM switch. Resistance value of 1st contact has 3.49, 2nd contact has 2.49, 3rd contact has 6.70, 4th contact has 5.81.

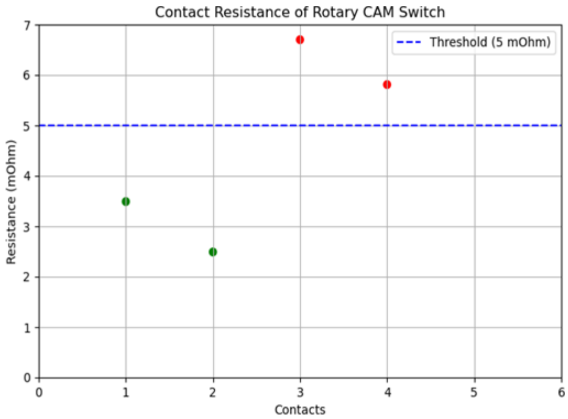

Fig. 9. contact resistance above allowed value

The presented graph depicts the contact resistance measurements of a 20 A, 3P, 2W, 90D Changeover CAM switch, with the X-axis representing individual switch contacts and the Y-axis indicating resistance values in milliohms (mOhm). The analysis reveals that two contacts exhibit resistance values below the predefined threshold of 5 mOhm, as represented by green markers, while the remaining two contacts exceed this threshold, as indicated by red markers. This deviation from the acceptable resistance range signifies that the switch is not operating within specified performance limits. The automated system processes the acquired data and identifies the malfunction, triggering a visual alert (red lamp) and an audible alarm, indicating improper switch functionality.

VI. CONCLUSION

This paper presents the development and implementation of an automated testing system for cam switch contact resistance and continuity using PLC and SCADA technologies. The proposed system enhances testing accuracy, repeatability, and efficiency by leveraging PLC-based control for precise measurement acquisition and SCADA for real-time monitoring and data analysis. The automation of the testing process significantly reduces manual intervention, thereby minimizing human error and optimizing operational efficiency.

The integration of SCADA provides a user-friendly interface for comprehensive data visualization, trend analysis, and automated report generation, facilitating data-driven decision- making and ensuring robust quality control measures. Furthermore, the system's scalability and adaptability make it a viable solution for a wide range of industrial applications, enabling manufacturers to achieve higher productivity and maintain stringent quality standards.

Future work may focus on extending the system's capabilities by integrating IoT-based remote monitoring, predictive maintenance algorithms, and machine learning techniques to further enhance reliability and performance. The proposed automated testing framework stands as a significant contribution to industrial automation, promoting precision, efficiency, and resource optimization in quality assurance processes.

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