IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

onal Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 10, May 2025 Impact Factor: 7.67

AutomatedUniversalEngineJunctionBoxTesting System using PLC and HMI

AtulBalad[1],ShrirajBalkawade[2],MaheshAdsule[3],SaurabhThorve[4]

Professor, Department of Electrical Engineering, Pune, India [1]

Student, Department of Electrical Engineering, Pune, India[234]

NBN Sinhgad Technical Institutes Campus, Pune, India

Abstract:*This paper discusses a new methodology for developing an automated test system of engine junction boxes using programmable logic controllers (PLCs) and human machine interfaces (HMIs). The legacy process of testing using human resources normally leads to long test times and unnecessary labor. In this instance, PLCs and HMIs will be used as a testing methodology for visual inspection and wire continuity testing. The junction box will be mounted in a test panel for branching inspection/potential connector usage. and the HMI will provide feedback to the operator in real time. In this automated process human testing will be eliminated and create more efficiency, accuracy and reliability in the test process.*

Keywords:
EngineJunctionBox,Automatedtesting,ProgrammableLogicControllers(PLC),VisualInspection,WireContinuity Testing, Human Machine Interfaces (HMI), Efficiency,Accuracy, Reliability

I. INTRODUCTION

In diesel engines and DG sets, a junction box provides the means of transferring electrical signals and power throughout the system. The integrity of junction box is important as there can be operational challenges when the junction box has failed. There are many different ways of testing the junction box, such as continuity, connector integrity and connector verification, and all of these tests are usually done manually. Manual methods can be slow and susceptible to human error when diagnosis testing for failures in the junction box. The system automates continuity testing; therefore, it can determine whether the electrical connections provide continuity within the junction box and are reliable. The PLC will conduct the tests in a linear fashion, and the HMI will inform users of any results in real-time, enabling users to address faults upon completion of the test or during the HMI results display. Continuity testing is automated.

What is Junction Box? An engine junction box is the new machine part that has entered automotive systems and industrial engine systems. A junction box is a formal structure of wires, terminals and connectors are used to transmitting electrical power, signals and control between separate components of the engine and/or control systems. Junction boxes act as the central nervous system of engines, taking electrical signals from its sensors, connected devices, and actuators, and relaying that information to the outputs, such as engine control unit (ECU).

With reference to diesel engines or DG sets the junction box is connected to the engine and to the control panel via multi-pin connectors and lugs. The "mating connector" provides a means to interface the junction box with the control panel By having the junction box wired by means of the appropriate multipin connector, the system can provide the flow of power distribution and control signals.

Today, many of the connections in an engine control system will involve multi-pin electrical connectors that join various components. For example, the Magnetic Pickup Unit (MPU) is an important part that measures engine speed and crankshaft position, then sends signals to areas like the Low Oil Pressure (LOP) switch (oil pressure measurement), the starter (engine ignition system), stop solenoid (engine shutdown), etc. Each of these connections are gathered in something called a junction block, or junction. The junction block is the device used to organize the, often, complicated electrical cabling into an aspect of an organized wiring system. The junction block has various types of connectors -

some for high-current lugs for the power electronics side of the engine control system (i.e., battery), some multi-pin connections that easily and effectively transmit thecontrol signals to and from the engine control modules. The junction block normally includes organization in the connection as well so it effectively increases reliability, decreases installation and breakdown time, and allows the classification of defective components during engine operation - a very rewarding aspect during the engine testing activities.The junction block enables specific connections, provides assurance that specific branch communications were achieved, and provides some assurance that the lugs that were connected with an electrical lug were properly attached, and functional. To summarize, a junction block is used in an engine control system to.

II. PROBLEM DEFINITION

Within a Diesel Generator (DG) system, the junction box serves as the central connection point for the sensor wires (such as temperature sensors, fuel level sensors, pressure sensors etc.) to monitor the workings of the generator. The plight rises when any of the various sensor wires become interchanged inside the junction box, which can result in a number of discrepancies, such as inappropriate readings, false alarms, possibly damaged sensors or control system simply due to misidentifying sensors/wires in the junction box wiring. The problem is due to the interchanged wiring thereof, or misidentifying the sensor connections inside the junction box, and provides inaccurate data to the DG's control panel or monitor system. Which can lead to various problems that prevents proper function, causes failures, or potentially unsafe operating conditions. Critical Issues:

2.1. False Readings: Interchanged wiring of sensors supplying false readings (pressure, temperature, fuel level) causing the DG to misinterpret its present condition.

2.2. Malfunction of Monitoring system: Interchanged wiring disrupts proper functioning of the monitoring or control systems including unnecessary alarms or critical notes failing to go off.

2.3. Safety: potentially unsafe operating conditions in which the DG continues to operate or get maintenance during ambiguous sensor indications (overheating, fuel issues, etc.) which could culminate in catastrophic engine failure if continued to operate unattended.

2.4. Troubleshooting Complications: When wires are swapped, recognizing the underlying cause of system errors or failures becomes difficult and can lead to lengthy troubleshooting times and downtime.

2.5. Damage to Equipment: In some cases, incorrect wiring can lead to an electrical short circuit or damage sensitive equipment, such as the sensors or the control module.

III. SCOPE & OBJECTIVES

Scope: The objective that is detailed below is a fresh approach to the automation of the testing of engine junction box using Programmable Logic Controllers (PLC) and Human-Machine Interfaces (HMI). Traditional testing technique involves manual operations that are less effective in terms of time and human or labour resources, but our recommendation provides a solution that has the potential for a hybrid system by primarily adhering to the PLC and HMI. The proposed testing system performs visual inspections and wire continuity tests all while using an embedded PLC. The junction box is fixed in place on a testing panel, individual virtual inspections are performed with visual inspections checking the wire integrity and assuring that the connectors and connections are accurate. All feedback is provided in real time with the use of a Human-Machine Interface (HMI). The automated testing process will save manual intervention while ensuring some level of proficiency and reproducibility.

Objectives :

1. Create and build a fully automated testing machine for engine junction boxes.
2. Implement PLC-based control logic to sequence through the tests.
3. Design a user-friendly Human-Machine Interface for operators to use.
4. Achieve accuracy and repeatability in test results.
5. Reduce test time by at least 70%.

6. Improve sustainability of the system & efficiency.
7. Wide consideration of CE levels for the standards withstand.
8. Provide data logging and analysis capabilities in real time.

IV. LITERATURE SURVEY

4.1 PLC and HMI in Automotive Electrical Testing (2020)

An Indian Perspective Automation is now the conduit for more efficient and precise methods of procedurally testing automotive electrical systems, and the Indian automotive sector is an ever-expanding area with a strong commitment to automation. In several recent research projects carried out in India, an increasing trend toward the testing of engine junction boxes with shaft-mounted relays, fuses and wiring circuits, increases the use of PLCs and HMIs. Companies like Tata Motors, Mahindra & Mahindra, and Ashok Leyland are all major companies with growing automation capabilities and increasingly PLCs will be made part of decision loops on the test benches that will suit well to testing procedures of electrical test units. M. Kumar et al. (2020) commented on the increased performance of test procedures for relays and fuses testing with automation applying PLC as an integrated approach with SCADA through the study published in the International Journal of Engineering Trends and Technology (IJETT). When the automation uses HMI development with PLC programming, it dramatically limits human involvement and test time for relay and fuse execution could effectively decrease from 60 minutes to 40, nearly 40% of test time to qualify the production units faster and more consistently.

4.2 Setting-Up a Universal Junction Box Test Bench (2021)

Indian research organizations in both academic and industrial contexts have undertaken the development of universal test benches or systems design considering a platform for potentially many variants and models of vehicles. The universal test benches are PLC (Programmable Logic Controller) logic base with modules to allow the engineer to switch effortlessly back and forth between the different test methods to assess the different wire configurations of unique junction boxes. An influential paper in this area writing about S. Raj et al., (2021) published in the Journal of Electrical Engineering, provide detailed demonstrations using the builder Siemens S7-1200 PLC with a HMI (Human-Machine Interface) system which then allowed for testing of multi- junction box types managing with a single viable test platform. Their design emphasis was using flexible programming logic under the umbrella of considering the universality of the test module, enabling that junction boxes with different wiring arrangements, and relay layouts needed only a minimum amount of manual reprogramming to be able to perform the test, allowing for a scalable, cost-effective solution for manufacturers.

4.3 The Role of HMI in Test Monitoring and Fault Diagnosis (2022)

Beyond basic control functionality, HMI systems are playing a growing role in test monitoring and diagnostics. Researchers in India have provided evidence to show how simple, graphical interfaces assist in real-time fault finding, quicker fault fixing, and better decision making on the factory floor. In a paper published in the International Journal of Scientific Research in Engineering and Management (IJSREM) (this paper written by P. Bhosale, and V. Gawande 2022), the authors proposed a custom-designed HMI interface for automotive electrical testing systems. The proposed HMI has a touchscreen layout that enables users to navigate in a simple manner through a number of different test sequences, start test diagnosis and access performance metrics. Fault alerts were colour-coded, and quick access to historical test data logs simplified the fault isolation process and improved traceability ofdefects. These aspects are essential to maintaining high-quality assurance standards, particularly in situations involving large constraints of manufacturing processes.

4.4. Utilizing LabVIEW and SCADA in Conjunction with a PLC for Advanced Analysis (2020)

Although PLC and HMI form the basis for most automated test systems, some researchers in India have gone a step further in combining LabVIEW and SCADA platforms within the test environment. Hybrid models are extremely useful for applications needing measurement of electric parameters or advanced data analytics. For example, a project

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 5, Issue 10, May 2025 Impact Factor: 7.67

report at VIT Chennai (2020) described the development of an automated test rig for engine wiring junction boxes that used PLC control logic with data acquisition in LabVIEW. The study's use of LabVIEW afforded the authors to monitor voltage, current, and signal integrity at a more granular level in each test phase. The software's ability to display trend information and real-time graphs in LabVIEW would have enabled further analysis of the behavior of components across changing load conditions—something that would be difficult to discern with a PLC-HMI system.

4.5. Industrial Adoption and Case Studies in India

The industrial significance of the research endeavors become invested have been their industrial deployment. Notable automotive companies, such as TVS Motors and Bosch India, have successfully deployed a PLC-based automated test system on their production lines for engine junction boxes. The internal R&D reports from both these companies show that using such systems has led to improved throughput, repeatability of tests, and low number of rejected units due to electrical faults. The case studies demonstrate that automation has had real benefits and that the Indian industry is primed to adopt smart manufacturing strategies. The continued collaboration between academia and industry also suggest that there is hope for advanced IoT and AI-enabled test systems in the near future.

V. METHODOLOGY

5.1 Project Design and Architecture

The design of an automated wiring junction box testing system is based on an integrated set of hardware and software components to effectively function in conjunction with one another. The centralized part of the system is defined by a 24 V DC power supply that provides consistent and stable power to the components which comprise the system, most importantly the digital input and output modules. The responses of the output and input modules require well regulated voltage to be able to fully utilize the components for testing purposes. The testing process is initiated by the Digital Output Module which sends out precise electrical signals through the wiring junction box. The signals flow down each wire in the junction box allowing the system to test for electrical continuity, which is essential for confirming that each wire is terminated properly and will carry current. The main objective is to verify that all connections in the junction box are properly constructed functionally. The testing system item we have been discussing is the wiring junction box itself, which is an electrical junction box that connects multiple subsystems with electrical transmission. The digital output modules well well-defined orders that are able to flow through wires. The Digital Input Module monitors all return signal(s) and will confirm that the wire is intact if the signal successfully travels through the wires without interruption.

The user receives the test results instantly from a Human-Machine Interface (HMI). The HMI has a green light for a successful continuity test and a red light when a break or other issue occurs. This displays to the user the status of the wiring, allowing for on-the-spot corrective action if necessary. The whole operation is controlled by a WAGO 750-8000 PLC serving as the main controller. This instantiates test signals through the 750-1504 Digital Output Module, and each step of the test completion is handled correctly and due diligence. Should any inconsistencies arise with the input from input module, such as loss of signal or wiring issues, it would catch all issues right away so that troubleshooting may happen correctly and with expediency. Most of the time, the user may only see the HMI interface when interacting with the system, as it provides results for immediate feedback butalso controls the flow of the operation. All of these devices are part of the WAGO ecosystem and comprise all of the working parts in a cohesive and complete automation suite, which allows for better development flexibility and the ability to complete development and testing in an all-in-one application. To program and control the system deployment, we utilized Codesys V3.5 software environment, which allows integration, open platform compatibility, and cross-functional development for really a complete automation solution by utilizing a single development tool, we have simplified complexity, accelerated deployment, and reduced total engineering costs—while implementing a highly effective automated testing solution.

5.2 Technical Specifications

5.2.1 Software Specification

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 5, Issue 10, May 2025 Impact Factor: 7.67

WAGO has created a productive ecosystem specifically aimed at machine-building and engineering automation systems. The integrated development environment enables a superior quality of design, decreases engineering costs, and dramatically reduces time-to-market, even when faced with increasingly complex requirements from customers. For this project, we utilized WAGO's Codesys Version 3.5.12.10, which is an all-inclusive software development environment for the automation sector that takes time and worries out of projects and adds insight to the developer. Codesys allowed us to design, program, and simulate our junction box testing automaton. Two elements of Codesys facilitated our implementation.

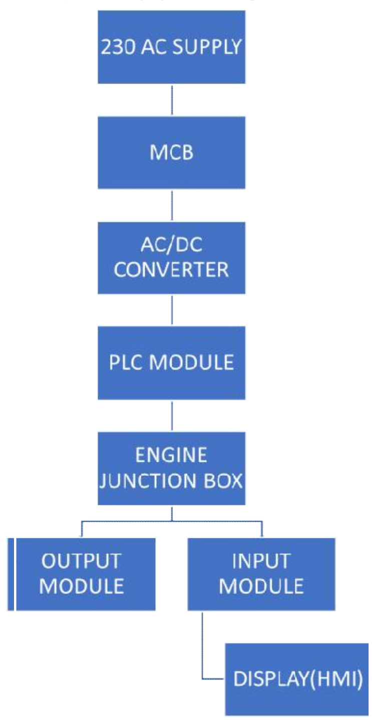
5.2.2 MAP View for HMI Design

The Human-Machine Interface was built with MAP View, a powerful design platform that is native to Codesys. MAP View uses an HTML5-based framework, which made it easy to build an intuitive and interactive HMI for the system. The interface was made interactive by presenting test results, sensor data, and system statuses that would allow the user to track wire continuity and connector health in real-time. The presented graphical layout also made it easy for the operator to interact with the system so that the testing was as transparent as possible.

5.2.3 Ladder Logic (LD) Programming

The test system logic and programming was implemented using Ladder Logic (LD), which is a common language used for automation programming. LD is visually user-friendly in that it allows conditional checks, loops, and real-time decision making to be implemented visually. Through the logic diagram, we were able to use all aspects of LD programming in the management of the logic, including handling all sensor data management, triggering fault alerts, regulating time and order of the test sequence, etc. The ability to use different layers to modularly manage sections of control logic dependent on the type of sensor was specifically helpful when managing multi-pin connectors. Additionally, LD made it easy for us to represent IQH sensor inputs and outputs easily to flow logically between process work and be responsive for feedback between the sensors and HMI.

VI. BLOCK DIAGRAM



VII. FUTURE SCOPE

Our Automated Universal Engine Junction Box Testing System offers great potential for support and enhancement, as technology will only continue to evolve with the introduction of smart technologies and newer functionalities.

One of the most exciting opportunities will be the connection of the system with the Internet of Things (IoT) to send the data from the testing process to cloud platforms in real time. This would allow engineers or supervisors to monitor the system from anywhere in the world, track performance, and pull historical test records. This provides not only more traceability but also indicates to any operator that maintenance may be necessary, improving reliability in the long run.

With the integration of Artificial Intelligence (AI), the system could use machine learning algorithms to recognize previous test patterns to predict potential wiring faults before they are produced. A predictive analysis would decrease downtime significantly, while increasing the quality of the electrical components being tested.

Stepping into the future we expect the testing system to be much more modular and portable. We could see less of a complete testing system that was tied to a sizable fixed layout and with the evolution we envision possibly move towards smaller, wireless systems that would be easier to carry and move ideal in servicecenters and for on-site quality checks. It would be a great step to provide more support to the testing in easier to deploy ways to aid in testing in the automotive service sector.

As we know it across dynamic working environments. We can expect this system to continue to evolve from the testing system regarding the convergence of Industry 4.0 standards. What that means, is that it will not only be a standalone device, but it will have the features to now connect with other machines, exchange data automatically and integrate into the smart factory platform. In manufacturing automation, a connected production line is crucial for transforming the testing solution along this line into an integral part of an ultra-reliable and unbroken manufacturing line. We could also look to see expansion that revolves around the limits of what represents Advanced Diagnostics and Extended Capabilities.

For example, the testing system can move towards capabilities such as signal integrity, digital fault heat mapping and also diagnostics at the component level. Overall, we see overall development that is demonstrating processes that can do a better jobof becoming smarter, faster, greater, connected answers, all relative and in accordance to advancing automotive manufacturing and constant quality assurance measures.

VIII. CONCLUSION

The Automated Universal Engine Junction Box Testing System developed with PLC and HMI has demonstrated precisely how automation can increase accuracy, efficiency, and reliability in testing within the automotive industry. This project achieved its goals by creating a universal platform for testing any type or model of engine junction box. Creating an automated PLC system for quickly identifying wiring deficiencies. Designing an interface (HMI) that is easy to operate and allows for real-time monitoring and control. Thoroughly testing the system to ensure accurate, precise, and repeatable operation.

The automated system saved nearly half the testing time of manual testing methods while overriding manual methods in accuracy. The PLC automation yielded reliable, repeatable results and mitigated human error. The HMI interface made a user friendly experience far superior to having to stare at a monitor and being able to see results and troubleshoot immediately. Suggestions for Improvement Consider using Industry 4.0 like IoT or & AI for smarter diagnostics and predictive maintenance. Develop a mobile app to allow for remote monitoring and control of the testing system. Expand system capability to test not just junction boxes but additional engine components as well.

Project contribution This project makes a meaningful contribution to the burgeoning field of automotive automated testing, through the increased efficiency, and reliability, of testing; Greater integrity, and improved reliability of electrical systems used in engines; Production cost savings, enabling greater competitiveness, through the use of better automation.

Acknowledgments We would like to thank Mr. Atul Balal, NBN Sinhgad Institute of Technology Campus, and our industry partners for their guidance, support, and providing the resources to accomplish this project.

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 5, Issue 10, May 2025 Impact Factor: 7.67

REFERENCES

[1] M. Kumar et al., "Automation-Based Testing Procedures for Electrical Units in Automotive," International Journal of Engineering Trends and Technology (IJETT), vol. 68, no. 3, pp. 45–50, 2020.

[2] S. Raj et al., "Development of Universal PLC-Based Test Bench for Automotive Junction Boxes," Journal of Electrical Engineering, vol. 10, no. 2, pp. 22–29, 2021.

[3] P. Bhosale and V. Gawande, "HMI-Based Real-Time Fault Diagnosis in Automotive Electrical Testing," International Journal of Scientific Research in Engineering and Management (IJSREM), vol. 4, no. 7, pp. 85–90, 2022.

[4] VIT Chennai Project Team, "Automated Test Rig for Engine Wiring Junction Boxes using LabVIEW and PLC," Project Report, VIT University, Chennai, 2020.

[5] TVS Motors & Bosch India, "Internal R&D Report: Performance Review of Automated Electrical Testing Systems," Company Reports, 2021