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AUTOMATED LOOP CHECKING FOR INSTRUMENTATION SYSTEMS

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Abstract

This technical paper addresses the significant challenges associated with instrument loop checking in large-scale mega-projects, where thousands of loops must be verified within tight schedules. Achieving high accuracy and efficiency is crucial to meeting critical milestones without compromising quality. The paper introduces an innovative strategy that leverages a cutting-edge technology, newly implemented in Saudi Aramco projects in collaboration with Yokogawa. This approach not only reduces the time required for loop checking but also enhances precision, ensuring that project timelines and quality standards are maintained. Through a detailed case study, the paper compares traditional methods with this novel approach, providing practical insights and actionable recommendations for project managers and engineers. Ultimately, this work serves as a valuable resource for professionals involved in similar high-stakes projects, offering guidance that contributes to the successful and economically impactful execution of such ventures.

In addition to presenting the technical aspects and benefits of the new technology, this paper also delves into the collaborative processes between Saudi Aramco and Yokogawa that were critical in driving the successful implementation of this solution. It highlights the importance of cross-disciplinary teamwork and the integration of advanced automation tools in overcoming the logistical and operational challenges inherent in mega-projects. The paper also discusses the lessons learned during the implementation phase, including risk management strategies and the adaptation of best practices from previous projects. By examining these elements, the paper provides a comprehensive overview of how innovative technologies, when effectively integrated into large-scale projects, can transform traditional workflows, leading to significant time and cost savings, as well as improved project outcomes.

Keywords: Instrumentation, Loop Check, Auto loop check, Gas Plant, PRM-CSP, Mega Project, Schedule

1.Introduction

In large-scale projects, particularly those involving complex industrial plants, the process of loop checking can be a monumental task, often requiring several months and thousands of man-hours to complete. This is primarily because, in conventional practice, the loop check process is typically conducted after the completion of critical preliminary tasks, such as piping hydrotests and the alignment and installation of equipment. The sheer scale of such projects introduces a variety of challenges, including issues related to communication across vast distances, the logistical difficulties of operating at varying elevations, and the potential for miscommunication among teams. These factors can significantly impact the efficiency and accuracy of loop checking, making it a critical area of focus in project execution.

Before delving deeper into the complexities and strategies associated with loop checking, it is essential to understand the pivotal role that instrumentation and control systems play in plant operations. These systems are integral to the plant’s safety, monitoring, and regulation of critical process parameters such as temperature, pressure, flow, level, and quality. By providing real-time data on these variables, instrumentation and control systems provides several safety layers in addition to empowering operators to make informed decisions, enabling them to maintain optimal operating conditions and prevent potential disruptions.

The accuracy and reliability of these systems are paramount, as they directly influence the safety, efficiency, and overall performance of the plant. Therefore, ensuring that all instrument loops are thoroughly checked and validated is not merely a procedural necessity but a fundamental requirement for the successful operation of any industrial facility.

1.1 History of Logical Programing (Instrumentation)

Robinson's landmark paper, published in 1965, marked a significant milestone in the field of automated reasoning by introducing the resolution rule. Resolution, a powerful inference rule, is particularly well-suited for automation within computer systems, laying the groundwork for advancements in logic-based computation [1].

In the early 1970s, the field of logic programming emerged as a direct extension of earlier research in automatic theorem proving and artificial intelligence. This period saw pioneering contributions from several key figures, with Kowalski and Colmerauer receiving most of the credit for the formal introduction of logic programming. Their work built upon the foundational ideas of predecessors like Green and Hayes, whose contributions to the development of logical systems also deserve recognition [2].

By 1972, Kowalski and Colmerauer had developed the groundbreaking idea that logic could be harnessed as a programming language. This realization transformed logic from a purely theoretical discipline into a practical tool for programming, enabling the creation of programs that could perform complex reasoning tasks. The introduction of logic programming not only expanded the capabilities of artificial intelligence but also influenced the design and implementation of future programming languages, laying the foundation for developments in fields such as expert systems, natural language processing, and more [2].

1.2 Programmed Control System (PCS)

The Process Control System (PCS) is a critical component in the management and operation of industrial plants, and it is typically divided into two primary subsystems: Distributed Control System (DCS) and Emergency Shutdown System (ESD).

The DCS is responsible for the continuous monitoring and control of process-related systems under normal operating conditions. It manages the distribution of tasks across various sections of the gas plant, ensuring that processes run smoothly, efficiently, and in accordance with predefined parameters. The DCS plays a vital role in optimizing plant performance, maintaining process stability, and ensuring the safe production of gas by adjusting variables like pressure, temperature, and flow rates in real-time.

On the other hand, the ESD system is designed to act in response to unsafe or abnormal conditions that could potentially endanger the plant, personnel, or the environment. As the DCS is considered as the first layer of protection, the ESD comes after as the second layer of protection in case the DCS couldn't control the readings within the normal or acceptable range. The ESD is programmed with various safety protocols to execute immediate protective actions when certain risk thresholds are crossed. These actions include implementing the single failure criterion, which ensures that no single point of failure can compromise the system's safety functions. Additionally, the ESD incorporates redundancy, ensuring that multiple backup systems are in place to maintain operational integrity even if primary components fail [3][4].

Other key features of the ESD include independence and diversity, which prevent common mode failures by using different technologies or methods to achieve the same safety goal. The system is also designed with fail-safety in mind, meaning that it defaults to a safe state in the event of a malfunction.

Moreover, the ESD provides Sequence of Event (SOE) in order to identify the first cause of trip during any investigations. Furthermore, the ESD can be manually initiated if automatic systems fail to respond, ensuring that operators have the ability to intervene directly. The system is also tasked with identifying and executing the appropriate protective actions tailored to specific emergencies, and all equipment used in the ESD is rigorously qualified to meet the highest safety standards.

By integrating these comprehensive safety measures, the PCS ensures both operational efficiency under normal conditions and robust protection in the face of potential hazards.

2. Loop Check

Loop Testing is a critical software testing technique that specifically targets the validation of loop constructs within a program. As an integral part of Control Structure Testing, which also includes path testing, data validation testing, and condition testing, Loop Testing ensures that loops function as intended under various conditions. This type of testing is essential for verifying the correctness and performance of iterative processes within software, particularly in systems where loops play a key role in decision-making and control.

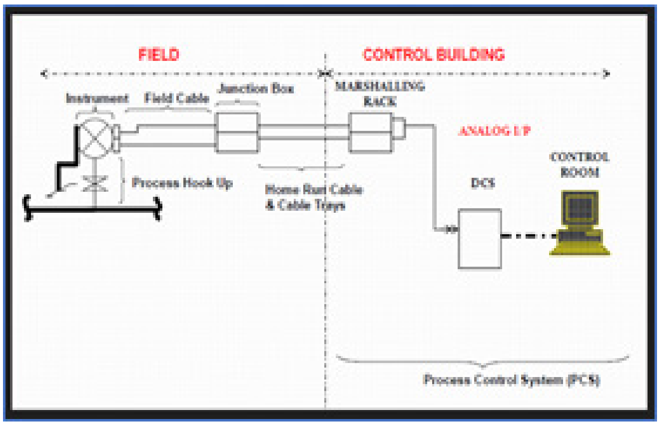
In the context of industrial automation and process control, loop testing is a vital step in the final phase before the commissioning of a Process Control System (PCS). This phase, known as loop check, involves a comprehensive verification process to confirm that all components within the control loops are correctly wired and functioning as designed. The primary objective of loop checking is to ensure the integrity and reliability of the control system by meticulously inspecting the connections and interactions between each element in the loop.

A control loop typically comprises of three main components: the transmitter or sensor, the process controller, and the final control element. The transmitter or sensor detects the process variable, such as temperature, pressure, level, or flow, and sends this data to the process controller. The controller then processes this information and makes decisions based on the predefined control strategy, sending appropriate commands to the final control element, which could be a valve, motor, or other actuator, to adjust the process accordingly [5].

During the loop check, each of these components is tested in unison to verify that the signals are accurately transmitted and received, that the control logic is correctly implemented, and that the final control element responds appropriately to the controller's commands. This process not only

ensures that the control loop is functioning as intended but also helps identify and rectify any wiring errors, calibration issues, or component failures before the system is fully operational. Additionally, the loop check ensures that process parameters and their corresponding alarms are accurately verified for the DCS operator.

By rigorously conducting loop checks, engineers can ensure the PCS operates reliably and safely, minimizing the risk of malfunctions that could lead to operational inefficiencies, safety hazards, or costly downtime.



Loop Check Synopsis, Figure.1

Before commencing the loop check, it is essential to complete several preliminary steps, including the review of marshalling terminations, JB (junction box) terminations, field installation checks, PCS (Process Control System), wiring continuity test, configuration reviews, site acceptance tests (SAT), and pre-loop testing. Once these tasks are completed, the loop check can begin.

2.1 Conventional Loop Check

Conducting a conventional loop check involves a lengthy and time-consuming procedure for each loop. Loop testing requires a coordinated effort between two crews: one stationed in the field and the other in the PCS (Process Control System) room, where the marshalling and system cabinets are located. Constant communication between the field crew and the PCS room crew is essential during device commissioning, necessitating reliable remote communication systems that are appropriate for the site's area classification [5].

Each loop must be tested thoroughly, starting from the field signal input and extending to the receiving instrument. This testing is conducted using specialized tools such as a manual hand pump, temperature calibrator, shaker table, and communicator. The communicator, in particular, is crucial for troubleshooting and configuring all instrument parameters For loops involving controllers, the output from the controller must also be verified through the final control element. This ensures the entire loop is functioning correctly.

Loops are identified and organized by tag number, and then grouped based on various criteria such as location, system, elevation, equipment, accessibility, or availability. However, when field instrument installation and cable termination are still ongoing, the field team may need to conduct loop checks and tests in a non-sequential order. This approach, while necessary at times, can be highly inefficient and time-consuming, especially when dealing with a large number of loops, as in this case, which could extend the process to over six months.

Efficient resource management is crucial to increasing productivity. Each team should include QC personnel, a site engineer, a foreman, an instrument calibrator, and helpers or laborers. Additionally, the team must be equipped with the necessary tools and equipment to carry out the loop checks effectively.

2.2 *Auto-Loop Check (Unconventional)*

Automated loop checking can be facilitated by software solutions from various vendors. In this case, the software used is the Plant Resource Manager Commissioning Support Package (PRM-CSP) developed by Yokogawa. The PRM-CSP is a powerful tool designed to streamline the loop checking process by automating critical tasks such as connectivity verification, range checking, data validation, and verifying the final element's source availability, either instrument air for air-operated valves or electricity for the motor operated valves (MOV). This software is particularly effective for both Foundation Fieldbus and HART devices, making it an invaluable asset during plant startup or maintenance phases.

By leveraging PRM-CSP, engineers can perform comprehensive loop checks more efficiently, ensuring that all devices are properly connected, configured, and functioning within specified parameters. The software reduces the need for manual intervention, minimizing human error and significantly cutting down the time required for loop testing. Additionally, PRM-CSP provides detailed reports and diagnostics that facilitate quick identification and resolution of any issues, thereby enhancing the overall reliability and safety of the plant's instrumentation systems [6][7].

This automated approach not only improves productivity but also contributes to maintaining high standards of quality and consistency throughout the commissioning process. As a result, PRM-CSP plays a crucial role in ensuring a smooth and successful plant startup, as well as in ongoing maintenance activities.

General Start-Up Procedure, Figure.2 [7]

Utilizing PRM-CSP significantly reduces the commissioning time for field devices while enhancing their overall reliability. Additionally, it improves the quality and consistency of the commissioning process, ensuring that field devices are configured and validated to the highest standards.

PRM-CSP is designed to streamline the commissioning process by automatically generating tasks based on the available device data and the selected task templates within the software. This automation ensures that each device is subjected to the appropriate checks and procedures, tailored to its specific requirements. During the execution of these tasks, PRM-CSP continuously monitors the status and progress, providing real-time updates to the commissioning team [7].

Upon completion of the commissioning tasks, PRM-CSP automatically generates detailed work reports. These reports offer valuable insights into the commissioning process, highlighting any issues encountered and the actions taken to resolve them. This comprehensive documentation not only supports quality assurance efforts but also serves as a reliable record for future maintenance and audits.

Integrating PRM-CSP into the commissioning workflow enables teams to achieve faster, more reliable, and higher-quality outcomes, significantly contributing to the successful and efficient startup of the plant.

2.2.1 Execution

PRM-CSP can be conducted in two distinct modes: Step-by-Step (Semi-Auto) and Continuous (Full-Auto), each offering different levels of control and automation tailored to the needs of the user.

2.2.1.1 Step-by-Step Mode (Semi-Auto)

This mode allows the user to manually advance through each step of the loop checking process. It provides a higher degree of control, enabling the user to carefully review and confirm each task before proceeding to the next. This mode is particularly useful in situations where precision and careful verification are paramount, as it allows for a more deliberate and thorough approach to loop checking.

2.2.1.2 Continuous Mode (Full-Auto)

In this mode, the system automatically progresses through the entire loop checking sequence without requiring manual intervention. Tasks are executed in a continuous flow, with the user monitoring the progress in real-time. Continuous mode is designed for efficiency, significantly reducing the time required to complete the loop check while maintaining high levels of accuracy. This mode is ideal for large-scale projects where time is a critical factor, allowing for rapid completion of loop checks across multiple devices or systems.

By offering these two modes, PRM-CSP provides flexibility in how loop checks are conducted, catering to both detailed, hands-on approaches as well as streamlined, automated workflows. This versatility ensures that the system can be adapted to various project needs, whether the focus is on meticulous, step-by-step verification or on achieving swift, comprehensive testing across large installations.

2.2.2 Reports

PRM-CSP also features automated work report generation, including loop check results, with the capability to produce three different types of reports:

2.2.2.1 Task Summary Report

Contains details about the tasks that are in the selected folder, and the devices that are associated with these tasks.

2.2.2.2 Device Summary Report

Contains details about the devices that are in a selected device folder, and the tasks that are associated with these devices.

2.2.2.3 Task Detail Report

Contains execution details about a selected task or the tasks that are in a selected folder, including specific check function details.

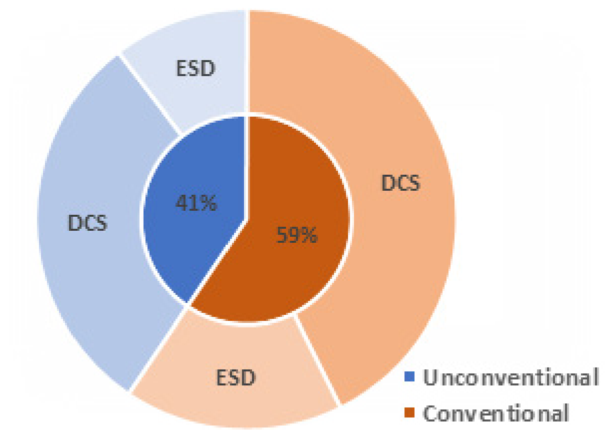
Report Samples, Figure.3

3.Implementation

The implementation of PRM-CSP is not universally applicable to all types of loops. The table below highlights the specific loops for which PRM-CSP can be effectively utilized. These loops are selected based on their compatibility with the system's capabilities and the benefits PRM-CSP offers in terms of efficiency, accuracy, and ease of commissioning.

System	Total Loops	PRM-CSP Applicable	Percentage
DCS	9522	3948	41.5%
ESD	3578	1375	38.4%
Total	13100	5323	40.6%

Applicable Loops for PRM-CSP, Table.1



Applicable Loops for PRM-CSP, Chart .1

For the DCS system, PRM-CSP is applicable exclusively to Foundation Fieldbus (FF) and HART loops. These digital communication protocols are fully supported by PRM-CSP, allowing for automated loop checking, data validation, and enhanced diagnostics. However, DCS loops that utilize conventional wiring, Discrete Input/Output (DI/DO) signals, and wireless communication are not compatible with PRM-CSP and therefore cannot be automated using this tool.

Similarly, for the ESD system, PRM-CSP is applicable only to HART loops. The software is designed to automate the testing and verification of HART-enabled devices within the ESD framework, ensuring high levels of reliability and safety. Other loop types within the ESD, such as conventional or DI/DO loops, are not supported by PRM-CSP, necessitating manual verification methods for these systems.

By focusing on FF and HART loops within DCS, and HART loops within ESD, PRM-CSP optimizes the loop checking process for the most advanced and widely used digital communication standards, while recognizing the limitations of the system when applied to other loop types.

4.Case Study

As a case study highlights the efficiency of using the PRM-CSP tool for loop checking in comparison to conventional methods. In this case study, a conventional loop check was conducted on a pressure transmitter. The process involved testing the readings for both the system side and the field indicator by gradually increasing the pressure in 500 psi increments until reaching 2000 psi. This method consumed approximately one hour (60 minutes) to complete it using the conventional loop check Process with Pressure Increments 500 psi with total pressure range 0 psi to 2000 psi.

In contrast, an automated loop check was conducted on the same pressure transmitter using the PRM-CSP tool. The process significantly reduced the time required, completing the loop check for one transmitter in 1 minute. Furthermore, the tool automatically generated reports, enhancing efficiency and documentation accuracy.

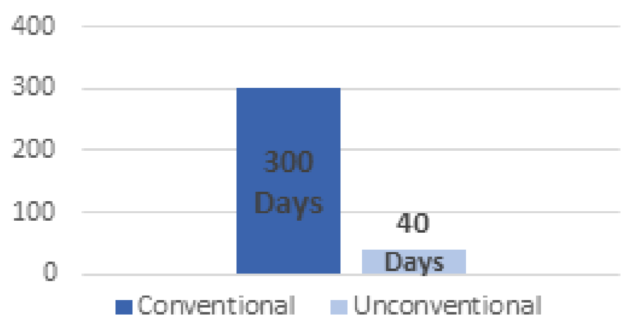
Automated loop check using PRM-CSP is 60 times faster than the conventional method, drastically reducing the time required from 1 hour to just one minutes for a transmitter. Additionally, the automation of report generation further streamlines the process, providing significant operational advantages in large-scale projects. This comparison effectively demonstrates the time-saving benefits and added value of using automated systems like PRM-CSP in complex and large-scale projects.

5. Compression

Overall, PRM-CSP offers several key advantages, including streamlined pre-inspection processes for loops, optimized utilization of human resources in the field, and enhanced reliability of testing results, as attached in Appendix A. By minimizing unnecessary time expenditures and reducing

potential risk points, PRM-CSP not only improves the efficiency of loop checks but also enhances the overall safety and effectiveness of operations. Additionally, the system's ability to generate accurate and comprehensive reports further improves the reliability of documentation, ensuring better availability and traceability of data throughout the loop checking process.

The chart below provides a clear comparison, illustrating the substantial benefits of PRM-CSP in terms of minimized schedule impact.



Duration Compression, Chart .2

6. Conclusions

In conclusion, the complexity and scale of loop checking in large-scale industrial projects highlight the critical need for efficient and reliable processes. Instrumentation and control systems are fundamental to plant operations, and their accuracy directly impacts safety, efficiency, and overall performance.

The PRM Commissioning Support Package (PRM-CSP), an example of automatic loop check, from Yokogawa significantly enhances the loop checking process by automating key tasks such as connectivity verification, range checking, and data validation, particularly for Foundation Fieldbus and HART devices.

Moreover, PRM-CSP offers several strategic advantages, including streamlined pre-inspection processes, optimized use of human resources in the field, and increased reliability of testing outcomes. By reducing unnecessary time expenditures and mitigating potential risk points, PRM-CSP not only improves the efficiency of loop checks but also bolsters the overall safety and effectiveness of plant operations. The system's capacity to automatically generate accurate and comprehensive reports further enhances the reliability of documentation, ensuring better data availability and traceability throughout the loop checking process.

Overall, integrating PRM-CSP into the commissioning workflow represents a pivotal advancement in managing the complexities of large-scale industrial projects, ultimately contributing to more successful, efficient, and safe plant startups and maintenance activities.

References

[1] Robinson, J. A. (1965). A Machine-Oriented Logic Based on the Resolution Principle. Journal of the ACM, 12(1), 23-41. doi:10.1145/321250.321253

[2] Colmerauer, A., Roussel, P. (1996). The Birth of Prolog. In K. R. Apt (Ed.), Handbook of Logic in Artificial Intelligence and Logic Programming (Vol. 5, pp. 3-36). Oxford University Press.

[3] Lipták, B. G. (2003). Instrument Engineers' Handbook, Volume Two: Process Control and Optimization (4th ed.). CRC Press.

[4] Considine, D. M. (1993). Process/Industrial Instruments and Controls Handbook (5th ed.). McGraw-Hill.

[5] Pressman, R. S. (2014). Software Engineering: A Practitioner's Approach (8th ed.). McGraw-Hill Education.

[6] Yokogawa Electric Corporation. (2016). PRM Commissioning Support Package (PRM-CSP) User Guide. Yokogawa Electric Corporation.

[7] Yokogawa Electric Corporation. (2018). Field Digital Solutions: PRM – Plant Resource Manager. Retrieved from Yokogawa Official Website.

Compression Table

Function	*Conventional*	*Unconventional*
Confirm the property and physical location and connection of field devices	It is necessary to disconnect the field devices to perform verification; 1.Disconnect the cable from the field device and check for an open circuit on the corresponding DCS TAG.	There is no need to disconnect the field devices. Verification can be done using HART/FF commands; 1.Utilize the SQUAWK command to send a signal from the DCS TAG. 2.Verify the SQUAWK signal on the LCD of the field devices directly in the field. 3.If the device does not support the SQUAWK command, use the simulate mode to set data to the device and verify the value displayed on the LCD in the field.
Verify the Performance and Precision of Field Devices in Loops	Performance and precision are confirmed manually by coordinating between the control room and field operators, often using walkie-talkies to check AI/AO parameters.	Although AI/AO parameter checking remains necessary, PRM-CSP streamlines the process by allowing loop checks to be conducted more efficiently. Devices can be grouped into tasks, enabling sequential (batch) execution when verifying multiple field devices consecutively.
Connectivity Check	The connection between the marshalling cabinet and the field device must be manually verified before starting the loop check.	This verification is integrated into the loop check process and can be conducted simultaneously.
Sending Signals for Testing	The Field Engineer must manually send a signal from the field device using a communicator each time a check is performed.	Once connectivity is verified, the Field Engineer no longer needs to send a signal manually for each subsequent check.
Measurement Values	Source and measurement values voiced by field side tester.	Values are automatically recorded with high accuracy in PRM-CSP.
Field Crew Moving	The field crew must physically move to each field instrument for every check.	The field crew does not need to move to each instrument for every check.
Environments Condition	Operations are limited by environmental conditions such as weather, time, and other factors.	Can operate with minimal impact from environmental conditions.

Reporting	Manual documentation is required for reporting purposes.	Reports are automatically generated by the system.
Re-testing	Requires additional time in the schedule for re-testing	Minimizes the impact on the schedule when re-testing is necessary.
Manpower	A crew of 25 people is required	A crew of 2 people are required
Time Consuming	A duration of 300 days for all required loops	A duration of 40 days is enough for all loop to be checked including the loops that will not be tested using auto- loop checking

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