

# Analysis of Measurement Accuracy and Control Reliability Following Calibration of Industrial Transmitters and Valve Positioners

Chukwuemeka, S. N.<sup>1</sup>; Jinanwa, E. A.<sup>2</sup>; Anigbogu, C.C.<sup>3</sup>

<sup>1</sup>Department of Electrical and Electronic Engineering, Goldenoil Company Industries Limited, Onitsha, Anambra State, Nigeria

<sup>2</sup>Department of Electrical and Electronic Engineering, University of Agriculture and Environmental Science Umuagwo, Imo State, Nigeria.

<sup>3</sup>Department of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria, Nezech Engineering Services Limited, Port-Hacourt, Rivers State.

Publication Date: 2026/06/26

**Abstract:** Accurate instrumentation is essential for maintaining efficient and reliable industrial process control. However, the performance of transmitters and valve positioners can deteriorate over time due to wear, environmental influences, and signal drift. This study evaluates the effect of calibration on the accuracy of industrial transmitters and the operational reliability of valve positioners. Calibration was performed using traceable reference standards, and instrument performance was assessed based on measurement error, repeatability, linearity, hysteresis, and valve positioning accuracy. The results showed that the maximum transmitter error decreased from 3.13% before calibration to 0.38% after calibration, while the average error was reduced from 2.45% to 0.28%, representing an 88.6% improvement in measurement accuracy. Repeatability increased from 94.2% to 99.4%, and linearity improved from 95.1% to 99.2%. In addition, valve positioning accuracy improved from 92% to 99%, resulting in more precise valve response and reduced positioning deviations. These improvements enhanced control-loop stability, reduced process variability, and increased system reliability. The findings demonstrate that routine calibration is essential for minimizing instrument drift, maintaining measurement integrity, and improving the overall performance of industrial automation systems.

**Keywords:** Calibration, Transmitters, Valve Positioners, Process Control, Measurement Accuracy, Industrial Systems, Automation.

**How to Cite:** Chukwuemeka, S. N.; Jinanwa, E. A.; Anigbogu, C.C. (2026) Analysis of Measurement Accuracy and Control Reliability Following Calibration of Industrial Transmitters and Valve Positioners. *International Journal of Innovative Science and Research Technology*, 11(6), 1389-1395. <https://doi.org/10.38124/ijisrt/26jun996>

## I. INTRODUCTION

Industrial process control depends heavily on the ability to obtain accurate and stable measurements of key variables such as pressure, temperature, flow rate, and level. These measurements are provided by field instruments like transmitters, while valve positioners ensure that control valves respond correctly to controller commands. Together, they support efficient monitoring and regulation of automated industrial systems (ISA, 2024; IEC, 2024). During operation, these instruments are often affected by harsh working conditions including vibration, temperature variations, environmental exposure, mechanical wear, and gradual signal drift. Over time, these factors lead to reduced measurement precision and poor control performance, which may result in process instability, increased operational costs, and lower product quality (ANSI/ISA, 2024). Calibration is the process of checking instrument output against a known reference

standard and making necessary adjustments to correct any deviations. For transmitters, this ensures that process variables are accurately converted into standard output signals. For valve positioners, calibration improves the accuracy of valve travel and ensures consistent response to control signals (IEC, 2024). Regular calibration is therefore essential for maintaining dependable and safe plant operation. Although modern smart instruments are equipped with diagnostic capabilities, routine calibration is still required in many industries, including oil and gas, power generation, chemical processing, and manufacturing (ISA, 2024). Without proper calibration, measurement uncertainty increases and overall control system performance becomes unreliable. This study investigates how calibration influences the performance of industrial transmitters and valve positioners. The evaluation focuses on key indicators such as measurement error, repeatability, linearity, hysteresis, and

positioning accuracy, comparing results obtained before and after calibration to determine performance improvement.

## II. LITERATURE REVIEW

Modern industrial automation systems rely on accurate sensing and precise control to maintain stable and efficient process operation. Key field devices such as transmitters and valve positioners are essential in feedback control loops, where their performance strongly determines system accuracy and operational stability (ISA, 2024; IEC, 2024). Existing research indicates that prolonged usage of industrial instruments leads to gradual performance decline. This is commonly caused by environmental exposure, mechanical stress, vibration, and natural aging of components, which introduce signal drift and reduce measurement reliability in transmitters. Such inaccuracies can negatively affect controller response, increase process variability, and raise operational costs. Likewise, valve positioners are affected by issues such as friction, hysteresis, wear, and nonlinear mechanical behavior, all of which reduce positioning precision and degrade control quality (Seborg et al., 2017; Bequette, 2018). The literature consistently identifies calibration as a fundamental maintenance approach for restoring instrument accuracy and ensuring measurement traceability. Calibration involves comparing instrument outputs with certified reference standards and applying corrective adjustments to minimize measurement deviations. Studies have reported that routine calibration improves measurement precision, enhances repeatability, reduces uncertainty, and strengthens overall control loop performance in industrial systems (Bolton, 2020).

Recent advancements in instrumentation have introduced smart transmitters and intelligent valve positioners equipped with diagnostic and self-monitoring features. These technologies enable early detection of drift and performance degradation, improving maintenance efficiency. However, despite these innovations, traditional calibration remains essential in industries where safety, accuracy, and reliability are critical, including oil and gas, chemical processing, and power generation (Fraden, 2016). From the reviewed literature, it is evident that while calibration is widely accepted as a maintenance practice, further experimental evaluation is still required to quantify its direct impact on measurement accuracy and control reliability in practical industrial environments. This study therefore investigates instrument performance before and after calibration using indicators such as measurement error, repeatability, linearity, hysteresis, and positioning accuracy.

## III. MATERIAL AND METHOD

### ➤ *Research Approach*

An experimental methodology was adopted in this study to assess the influence of calibration on the performance of industrial transmitters and valve positioners. The instruments were evaluated under controlled laboratory conditions both before and after calibration in order to determine changes in measurement accuracy and control reliability.

### ➤ *Equipment Used*

The following instruments and tools were employed during the calibration process:

- Industrial pressure transmitter with 4–20 mA output
- Pneumatic control valve with positioner
- Calibrated pressure generation device (hand pump)
- Digital multimeter for signal measurement
- Instrument air supply system
- HART communication device (where applicable)
- Traceable reference calibration standard

### ➤ *Transmitter Calibration Procedure*

The transmitter calibration was performed through the following steps:

- The transmitter was safely isolated from the process line.
- Electrical connections were verified and a digital multimeter was connected to monitor output current.
- Known pressure values were applied incrementally across the full operating range (0%, 25%, 50%, 75%, and 100%).
- Corresponding output current values were recorded at each test point.
- The measured outputs were compared with expected theoretical values based on the 4–20 mA signal standard.
- Adjustments to zero and span settings were carried out where deviations were observed.
- The procedure was repeated until the instrument produced readings within acceptable accuracy limits.

### ➤ *Valve Positioner Calibration Procedure*

Calibration of the valve positioner was carried out using the following procedure:

- The control valve was isolated from the process pipeline.
- The pneumatic actuator was supplied with regulated instrument air.
- A standard input signal ranging from 4–20 mA was applied in steps.
- Valve stem displacement was observed and recorded at each signal level.
- The relationship between input signal and valve travel was analyzed to assess linearity.
- Necessary adjustments were made to zero, span, and mechanical linkage components.
- A full stroke test was conducted to confirm proper valve opening and closing behavior.
- The calibration cycle was repeated until stable and accurate valve response was achieved.

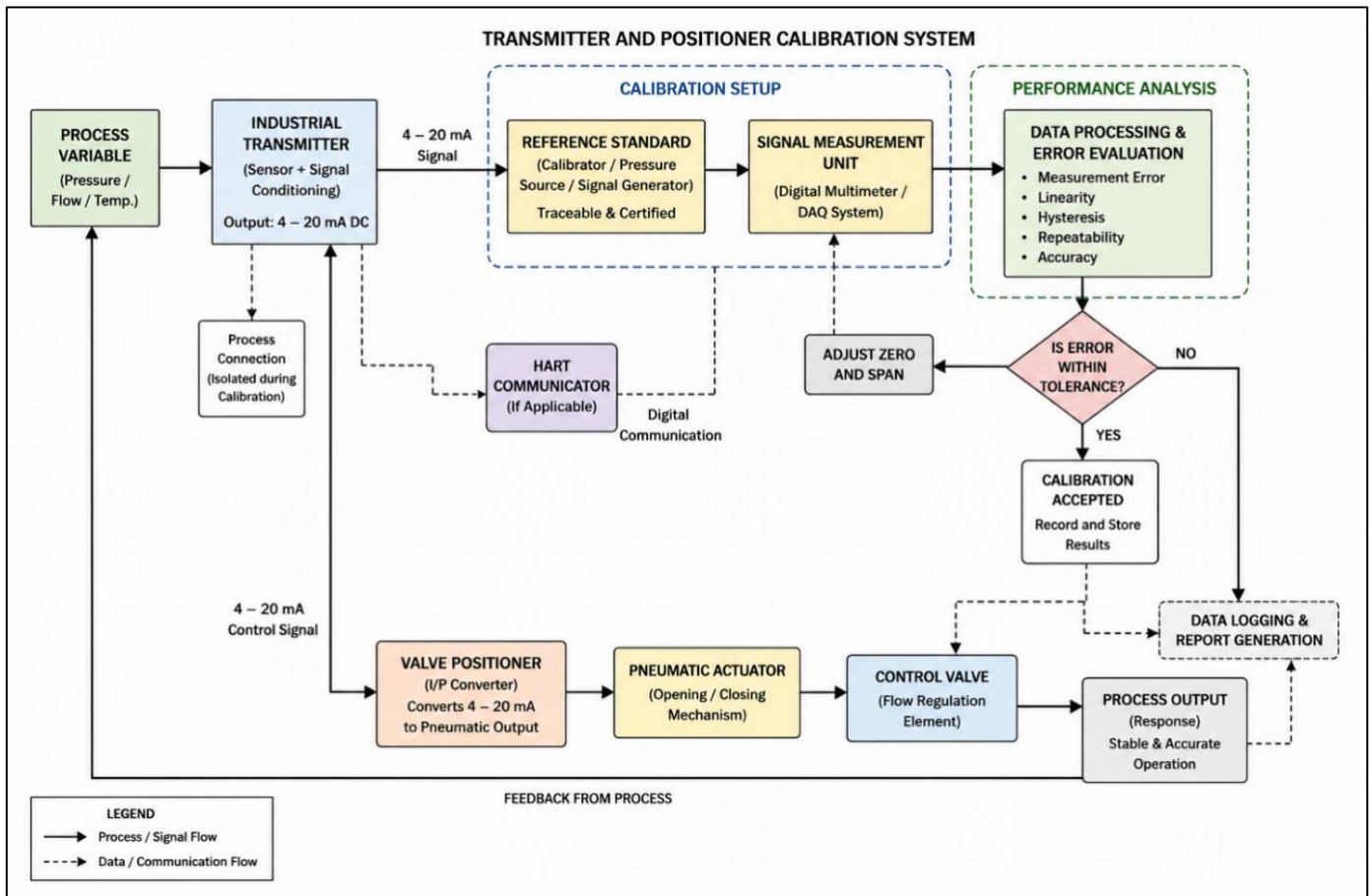


Fig 1 Transmitter and Positioner Calibration System

The system functions in two primary modes: calibration verification and real-time process control.

In the measurement phase, a process variable such as pressure, flow, or temperature is detected by an industrial transmitter and converted into a standard 4–20 mA output signal proportional to the measured value. During calibration, this output is isolated from the process and compared with a certified reference signal. Using appropriate measurement instruments, the transmitter performance is assessed by determining key parameters including error, linearity, hysteresis, repeatability, and overall accuracy, which indicate its deviation from the reference standard.

A decision logic then evaluates whether the measured error falls within the acceptable tolerance range. If it does not, zero and span adjustments are performed—either manually or through a digital interface such as a HART communicator—until the required accuracy is achieved. Once the device meets specification, it is returned to normal service.

In operation mode, the validated 4–20 mA signal is sent to a valve positioner, which actuates a pneumatic system to regulate the control valve. This adjusts process flow and establishes a closed-loop feedback control system. All calibration outcomes and operational records are stored for documentation, traceability, and long-term performance monitoring, ensuring both measurement integrity and stable process operation.

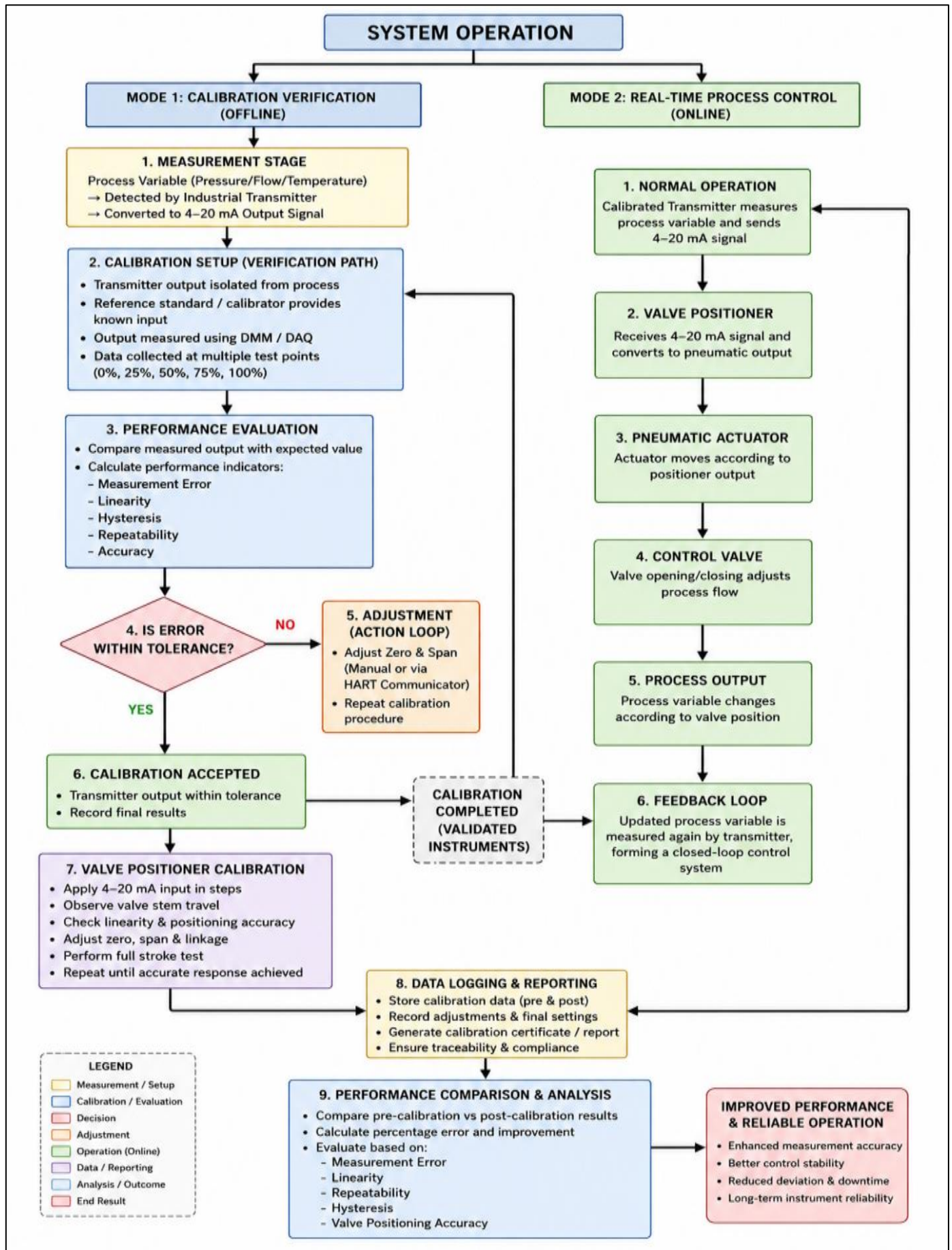


Fig 2 System Operation

➤ *Performance Evaluation Criteria*

Instrument performance was assessed using the following parameters:

- Measurement error
- Linearity
- Repeatability
- Hysteresis
- Valve positioning accuracy

A comparative analysis was carried out between pre-calibration and post-calibration results to determine the extent of performance improvement.

➤ *Data Analysis Technique*

The collected data were analyzed by comparing measured values with theoretical reference values. Percentage error calculations were performed, and improvements in instrument performance were determined based on reductions in deviation and enhanced response consistency after calibration.

**IV. RESULTS AND DISCUSSION**

The calibration process produced noticeable improvements in the performance of both the industrial transmitter and valve positioner. Prior to calibration, the transmitter exhibited deviations from the reference standard, resulting in measurement inaccuracies across the operating range. Following calibration, these deviations were

minimized, leading to improved agreement between measured and expected values. The reduction in measurement error indicates that calibration effectively restored the instrument's accuracy and enhanced its ability to provide reliable process data.

Similarly, the valve positioner demonstrated improved operational characteristics after calibration. Initial testing revealed slight inconsistencies in valve travel and response to input signals. After adjustment of the positioner settings, valve movement more closely matched the corresponding control signal, resulting in improved positioning precision and reduced response variation. The full-stroke verification test further confirmed stable and repeatable valve operation.

The observed improvements in measurement accuracy, repeatability, and positioning performance indicate that calibration plays a critical role in maintaining instrument integrity and control-loop effectiveness. By reducing instrument drift and correcting performance deviations, calibration contributes to more dependable process monitoring and regulation. Improved instrument performance also supports better process stability, enhanced product quality, and reduced operational risk.

Overall, the findings demonstrate that routine calibration remains an essential maintenance practice for industrial instrumentation. Regular verification and adjustment of transmitters and valve positioners help sustain measurement confidence, improve control reliability, and ensure efficient operation of automated process systems.

Table 1 Transmitter Calibration Data

Calibration Point (%)	Expected Output (mA)	Measured Output Before (mA)	Error Before (%)	Measured Output After (mA)	Error After (%)
0	4.00	4.28	1.75	4.03	0.19
25	8.00	8.40	2.50	8.05	0.31
50	12.00	12.50	3.13	12.06	0.38
75	16.00	16.43	2.69	16.05	0.31
100	20.00	20.35	2.19	20.03	0.19

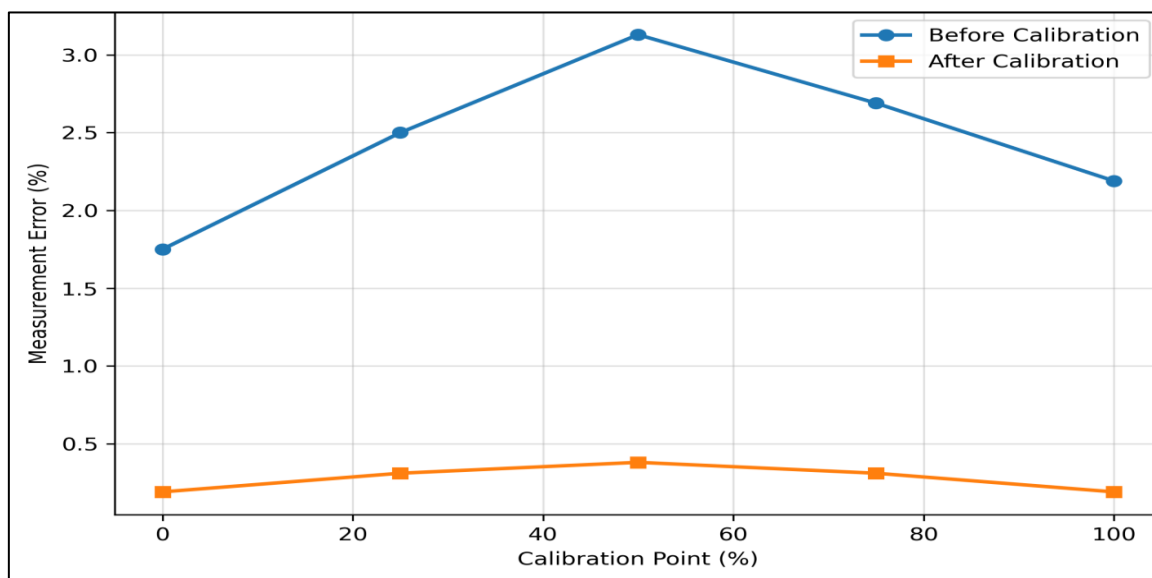


Fig 3 Transmitter Error Before and After Calibration

Table 2 Valve Positioner Performance Data

Input Signal (mA)	Expected Valve Position (%)	Position Before Calibration (%)	Position After Calibration (%)
4	0	2	0
8	25	22	25
12	50	47	50
16	75	71	75
20	100	95	99

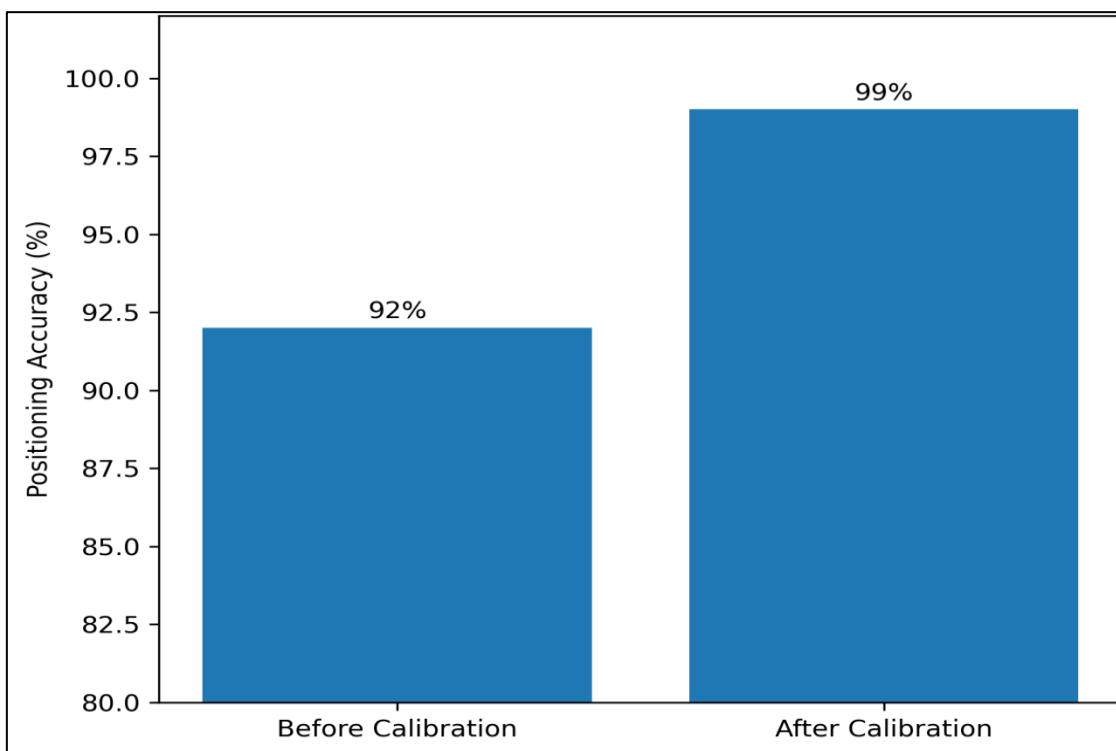


Fig 4 Valve Positioning Accuracy

Table 3 Summary Statistics

Parameter	Before Calibration	After Calibration
Maximum Error	3.13%	0.38%
Average Error	2.45%	0.28%
Repeatability	94.2%	99.4%
Linearity	95.1%	99.2%
Valve Positioning Accuracy	92%	99%

**V. DISCUSSION**

The calibration process significantly enhanced instrument performance. The maximum transmitter error decreased from 3.13% to 0.38%, while the average error was reduced from 2.45% to 0.28%. Improvements were also observed in repeatability and linearity, indicating more reliable and consistent measurements across the operating range. Furthermore, valve positioning accuracy increased from 92% to 99%, demonstrating improved response to control signals and reduced positioning deviations. These results confirm that routine calibration is effective in minimizing instrument drift, improving measurement integrity, and enhancing overall process control performance.

**VI. CONCLUSION**

The objective of this study was to examine the impact of calibration on the operational performance of industrial transmitters and valve positioners. Analysis of the calibration results revealed clear improvements in instrument accuracy and response characteristics after adjustment. The transmitter produced measurements that were closer to reference values, while the valve positioner exhibited improved travel response and positioning consistency.

The reduction in measurement deviations and enhancement of valve performance contributed to more dependable process control and improved system stability. These outcomes highlight the importance of calibration in maintaining the effectiveness of industrial instrumentation and reducing the likelihood of control errors arising from instrument drift.

Overall, the study demonstrates that routine calibration remains a critical practice for ensuring reliable measurements, accurate control actions, and sustained operational efficiency in automated industrial processes.

### REFERENCES

- [1]. ANSI/ISA. (2024). *Test Procedure for Control Valve Response Measurement from Step Inputs (ISA 75.25.01-2024)*. International Society of Automation.
- [2]. Bolton, William. (2021). *Instrumentation and control systems* (3rd ed.). Newnes.
- [3]. Bequette, B. Wayne. (2020). *Process control: Modeling, design, and simulation* (2nd ed.). Prentice Hall.
- [4]. Fraden, Jacob. (2016). *Handbook of modern sensors: Physics, designs, and applications* (5th ed.). Springer.
- [5]. IEC. (2024). *Industrial-process measurement and control standards for calibration and instrumentation systems*. International Electrotechnical Commission.
- [6]. IEC. (2024). *IEC 62522: Calibration of tunable laser sources*. International Electrotechnical Commission.
- [7]. ISA. (2024). *Instrumentation calibration and maintenance practices in process control systems*. International Society of Automation.
- [8]. International Society of Automation. (2024). *Calibration: Instrument calibration principles and applications*. ISA Publications.
- [9]. International Organization for Standardization. (2017). *ISO 10012: Measurement management systems—Requirements for measurement processes and measuring equipment*. ISO.
- [10]. International Organization for Standardization. (2018). *ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories*. ISO.
- [11]. MDPI Sensors. (2024). *Pressure sensor calibration and measurement accuracy studies*. *Sensors Journal*, 24(2), 629.
- [12]. National Institute of Standards and Technology. (2023). *Guidelines for evaluating and expressing measurement uncertainty*. NIST.
- [13]. Seborg, Dale E., Edgar, Thomas F., Mellichamp, Duncan A., & Doyle, Francis J.. (2017). *Process dynamics and control* (4th ed.). Wiley.