Random Pattern Test for Loop Calibration of HART Slave Device

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Acronyms

HART	Highway Addressable Remote Transducer
HS	HART Slave
MAX_VLU	Maximum Value
MIN_VLU	Minimum Value
PST	Partial Stroke Test
RPT	Random Pattern Test
SPA	Scattered Point Algoroithm
TP	Test Point

1. Introduction

Calibration is the set of instructions for fine-tuning the HART supported devices. This procedure is performed against the well-defined set of specifications by the product manufacturer. Calibration is an essential step in the industrial automation field to achieve highest quality of the product. Calibration is also defined as the publishing of data contains a calibration test report or calibration certificate that confirms the product used on whether the product meets its specifications. Calibration is performed by comparing the known set of measurement values includes defined acceptable tolerance or limit with the observed set of measurement values captured using the slave device.

Control valves may open and close proportionally and vary the degree of travel depending on the applied control signal. For explanation of the concept, the control valves which are used in a wide range of processes are considered as example. Signature Test and Partial Stroke Test are few of the existing tests used in the industry to measure the valve performance. The intention of this white paper is to introduce a new test called Random Pattern Test for the HART supported slave devices operates over 4-20mA analog current.

2. Calibration

2.1 Importance of Calibration

Calibration is crucial in the industrial automation sector to achieve quality. Calibration is vitally important in the industry sector where measurements are significant, it allows users to have confidence in the performance that are monitored, recorded and subsequently controlled.

Calibration is to inform the user on the device performance by using the standard or baseline equipment of higher accuracy to adjust, correlate, detect, document and rectify the accuracy of the device.

The accuracy of the standard measuring values should be ten times the accuracy of the measuring device. Regular performance checks with a standard calibrator is important due to the following factors.

1) Variation in electronic instruments performance against time, exposure of the electronic circuitry parts to atmospheric conditions such as humidity, temperature and vibration.
2) Certification Standards and Regulations governing safety and environmental protection.
3) Quality standards.
4) Commercial requirements.

Regular calibration is a wise idea for the users because device performance checks will often fail to detect the problems that are not directly caused by the instruments. HART protocol is an industrial communication protocol having hybrid analog and digital data.

HART is communicated over 4-20mA analog current loops with the host system through pair of analog wires as shown in Fig. 1.

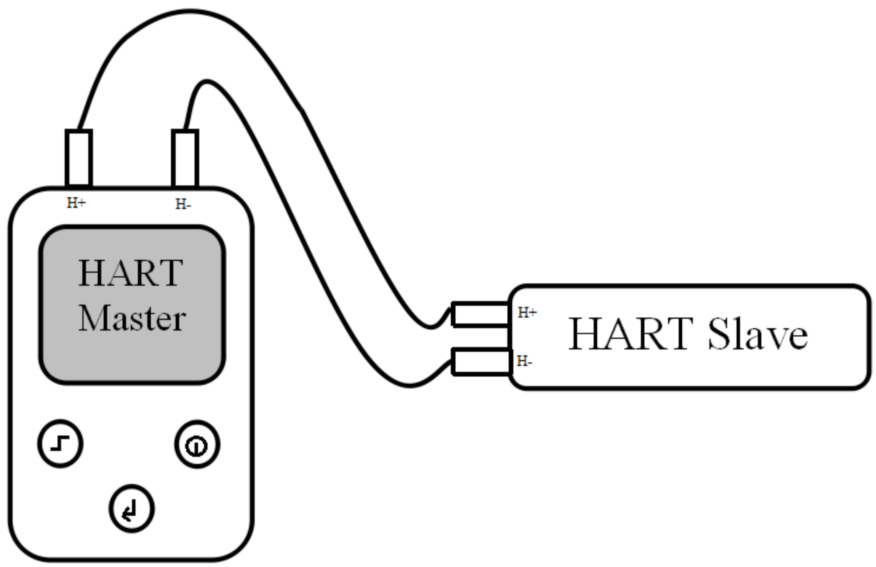

Fig.1 HART Master and Slave Connection

Precision and reliability are key factors for providing correct measurements, which are vitally important and crucial for decision-making and device performance in a number of professions including the medical field and automotive, agricultural and engineering industries. Hence, all measuring instruments need to be quantified with a higher standard of verification in order to produce reliable data readings for accurate and decisive action.

The verification process known as Calibration is used to authenticate and confirm the readings of any given tool or instrument matched against a particular standardized benchmark. Measuring equipment that does not reach a specific level of tolerance will require some form of

Calibration, which confirms it is then working according to manufacturer's guidelines and international standards.

2.2 Calibration Tests

2.2.1 Signature Test

Signature Test creates a baseline of valve performance before shipping to market. This baseline provides a starting point for future data comparison. Also, it enables the user to track the operating condition of the control valve and maximize valve performance. The standard instrument obtains the first valve signature by causing a different set of control signals to be applied to the valve and capturing the response data mentioning the actual valve positions related to the applied input control signals.

The analytical device may generate an image including a graphical representation of the first valve signature and a second valve signature that was measured prior to or after the first valve signature. A set of valve positions and the corresponding control signals is known as a "valve signature." A graphical representation of the valve signature can be useful in assessing various characteristics of a valve. There are different types of valves being used in industry, and each valve may have a unique valve signature. A valve signature may vary depending on the application and process parameters such as flow, pressure, temperature, and valve settings, among others.

2.2.2 Partial Stroke Test

Partial Stroke Test is used to reveal the valve design issues without affecting the production. Partial Stroke Testing is not an isolated measure that will resolve any fault in the valve design. The testing is performed by moving the valve from its full open position to a partially closed position (i.e. 90%) and then back to full open position. PST is used to confirm that the valve is working and does not require a costly process shutdown.

The valve is not fully stroked, but moved by 10 % for example, without influencing the process or at least without the need for shutting down the process. In order to have a high diagnostic coverage, it is beneficial to arm the testing procedure with elaborate means.

3. Random Pattern Test

3.1 Test Description

Random Pattern Test(RPT) is the new approach for calibrating the HART Slave(HS) devices. It helps the field user to measure the performance of HS device in all possible operating ranges of 4 to 20mA input. Performance includes the speed, accuracy, robustness, reliability and quality of the HS device.

This test is generating all possible test points from 4.00mA to 20.00mA. This test is designed with 2-point resolution in the floating point range. The first and last point in the input current range is considered as 4.00mA and 20.00mA respectively.

The pattern is generated using Scattered Point Algorithm(SPA). This algorithm considers the first test point as 4.00mA herein after called as Test Point 1(TP-1), second test point as 4.01mA herein after called as Test Point 1(TP-2) and so on.

The last point is 20.00mA herein after called as Test Point N(TP-N). In this test, different 16 input current values are applied to the valve and the performance of the valve position is captured.

3.2 Analysis

Example 1:

SPA takes the current signal values of TP-1, TP-2 through TP-16 as input as mentioned in Table 1. In this example, the test point TP-1 value is 5.04mA, test point TP-2 value is 14.10mA and up to the TP-16 value of 7.57mA.

The algorithm generates the random test pattern as output as shown in Fig. 2.

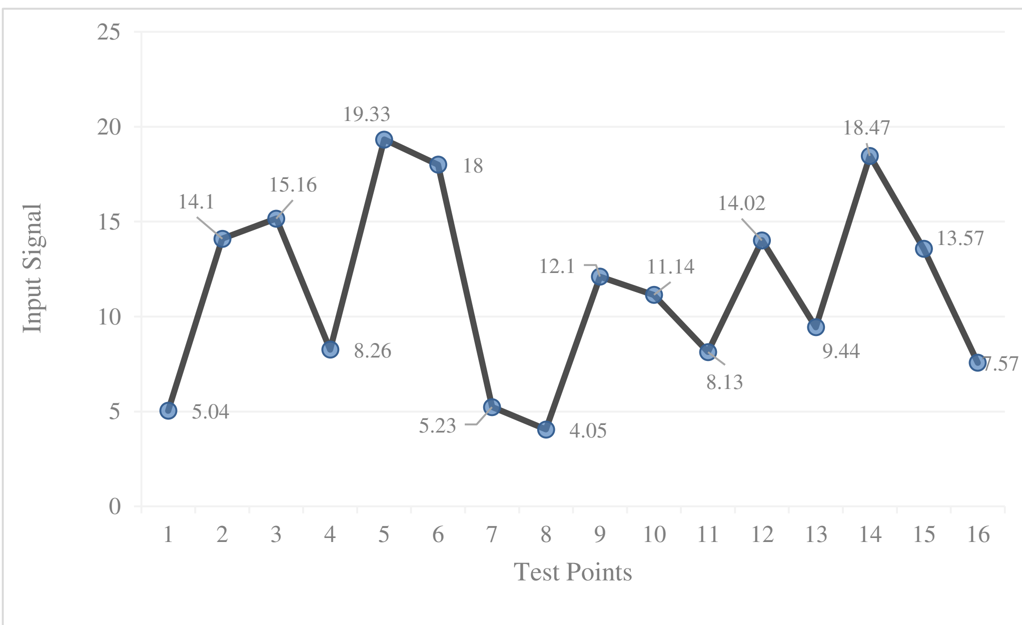

Fig.2 Output Pattern-1

Table 1 Input Signal Pattern-1 and Captured Position Values

Test Points	Input Signal (mA)	Captured Position Values (Percentage)
TP-1	5.04	6.50
TP-2	14.10	63.12
TP-3	15.16	69.75
TP-4	8.26	26.62
TP-5	19.33	95.81
TP-6	18.00	87.50
TP-7	5.23	7.68
TP-8	4.05	0.31
TP-9	12.10	50.62
TP-10	11.14	44.62
TP-11	8.13	25.81
TP-12	14.02	62.62
TP-13	9.44	34.00
TP-14	18.47	90.43
TP-15	13.57	59.81
TP-16	7.57	22.31

The position values will vary according to the input current applied by the user to the HS device. The HS device is measured against the output pattern-1 values for performance and the captured valve position values are mentioned in Table 1. The valve performance is plotted for the captured position values against the input signal values as shown in Fig. 3.

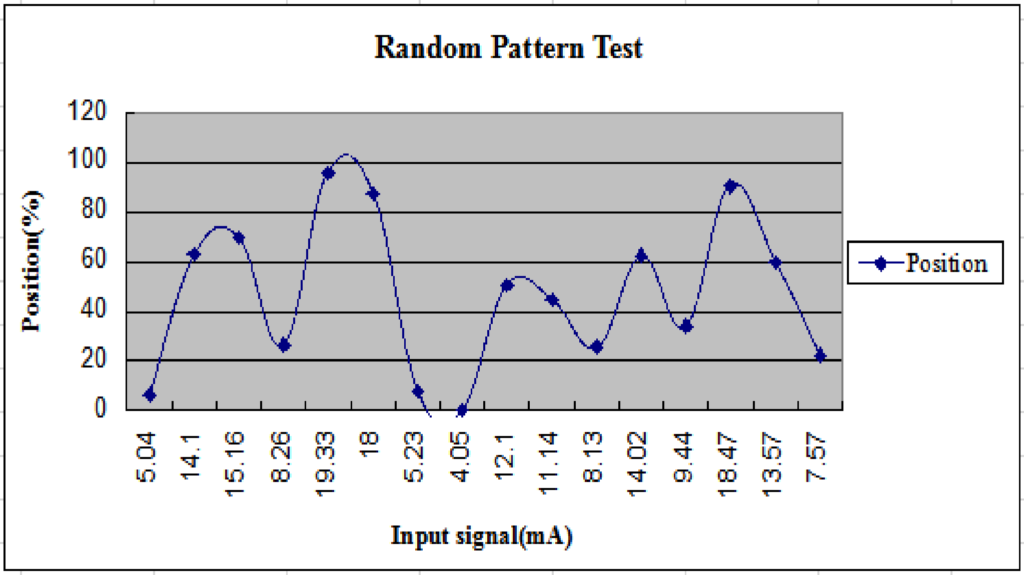

Fig.3 Valve Performance

Example 2:

Similarly, for another set of sample values of TP-1, TP-2 through TP-16 as input as mentioned in Table 3, the SPA generates the random test pattern as output as shown in Fig. 4. In this example, the test point TP-1 value is 12.63mA, test point TP-2 value is 8.72mA and up to the TP-16 value of 16.44mA.

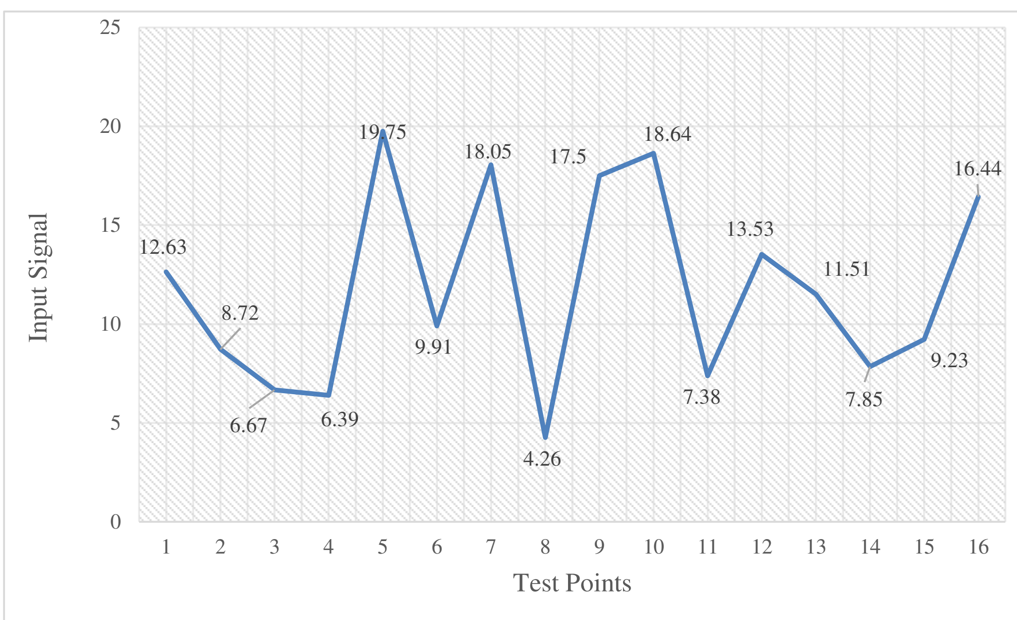

Fig.4 Output Pattern-2

Table 2 Input Signal Pattern-2 and Captured Position Values

Test Points	**Input Signal (mA)**	**Captured Position Values (Percentage)**
TP-1	12.63	53.93
TP-2	8.72	29.50
TP-3	6.67	16.68
TP-4	6.39	14.93
TP-5	19.75	98.43
TP-6	9.91	36.93
TP-7	18.05	87.81
TP-8	4.26	1.62
TP-9	17.5	84.37
TP-10	18.64	91.50
TP-11	7.38	21.12
TP-12	13.53	59.56
TP-13	11.51	46.93
TP-14	7.85	24.06
TP-15	9.23	32.68
TP-16	16.44	77.75

The HS device is measured against the output pattern-2 values for performance and the captured valve position values are mentioned in Table 2. The valve performance is plotted for the captured position values against the input signal values as shown in Fig. 5.

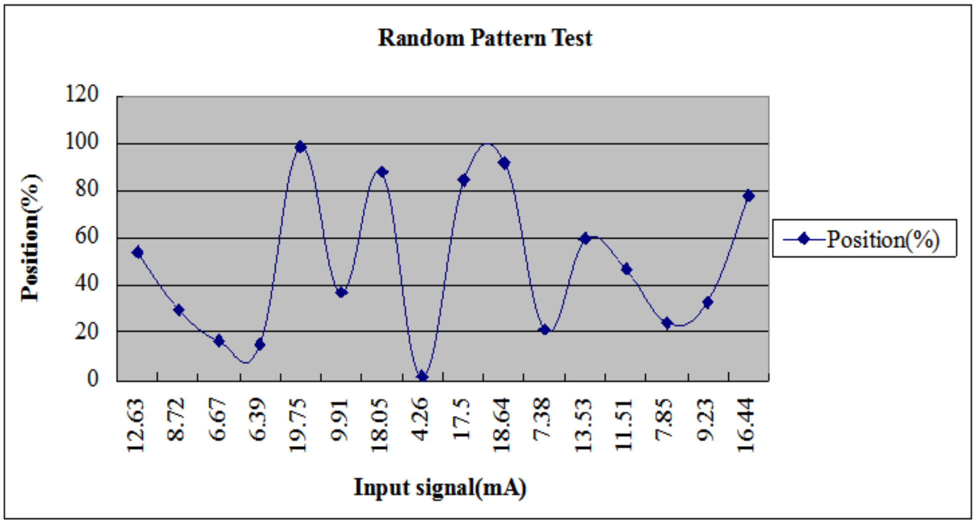

Fig.5 Valve Performance

3.3 Algorithm

The algorithm checks for the type of valve from the configuration. In either case, the minimum current is stored in the value of 'n' which is the test point. The input signal is re-calculated with 'factor' value defined by the algorithm every time. The calculated input signal value is checked for the range between the MIN_VLU and MAX_VLU value both inclusive. Based on the range check, the outcome of the result will be successful or unsuccessful. The decision is made to consider the input signal value for pattern generation. Either MIN_VLU or MAX_VLU value range check failure will result in further re-calculation to bring the input signal value within the range of MIN_VLU to MAX_VLU both inclusive.

3.4 Measurement and Result

For explanation, valve position values are considered as an example to depicts the performance. The calculated input signal is applied to the valve and the position response of the valve is captured. The 'n' number of values are applied and the respective responses are captured. The deviation of the valve position is calculated and accordingly the valve characteristics is determined and the result is sent to the user. The RPT result may be any one of the condition as Perfect, Good, Marginal or Bad state.

3.5 Usage of RPT

1) End user can capture the valve performance in various dimensions (speed, accuracy, robustness, reliability and quality) in all possible operating ranges of 4 to 20mA input.
2) End user can measure the smoothness and the ability of the valve to respond to abrupt inputs.
3) Algorithm and solution implementation time and cost is less.
4) Used for testing the industrial valves.

4. Summary

Calibration defines the accuracy and quality of measurements recorded using an equipment. In Signature test, the analytical device may generate an image including a graphical representation of the first valve signature and a second valve signature that was measured prior to or after the first valve signature and so on. Partial stroke testing is not an isolated measure that will cure any deficiency of the valve design. Partial stroke testing is not an isolated measure that will cure any deficiency of the valve design. Random Patter Test is the new approach for calibrating the HART Slave(HS) devices. It helps the field user to measure the performance of HS device in all possible operating ranges of 4 to 20mA input. This test is generating all possible test points from 4.00mA to 20.00mA. This test is designed with 2-point resolution in the floating point range. The pattern is generated using Scattered Point Algorithm(SPA). RPT captures the valve performance that includes the speed, accuracy, robustness, reliability and quality of the HS device.

5. References

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