3051S HART Pressure Transmitter with Advanced Diagnostics

Statistical Process Monitoring Diagnostic Technology

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Introduction

Emerson Process Management has developed a unique technology, Statistical Process Monitoring, that provides a means for early detection of abnormal situations in a process environment. The technology is based on the premise that virtually all dynamic processes have a unique noise or variation signature when operating normally. Changes in these signatures may signal that a significant change will occur or has occurred in the process, process equipment, or transmitter installation. For example, the noise source may be equipment in the process such as a pump or agitator, the natural variation in the DP value caused by turbulent flow, or a combination of both.

The sensing of the unique signature begins with the combination of a high speed sensing device, such as the Rosemount 3051S Pressure Transmitter, with patented software resident in a Diagnostics Feature Board (Figure 1) to compute statistical parameters that characterize and quantify the noise or variation. These statistical parameters are the mean and standard deviation of the input pressure. Filtering capability is provided to separate slow changes in the process (due to setpoint changes) from the process noise or variation of interest. Figure 2 shows one example of how the standard deviation value is affected by changes in noise level while the mean or average value remains constant.

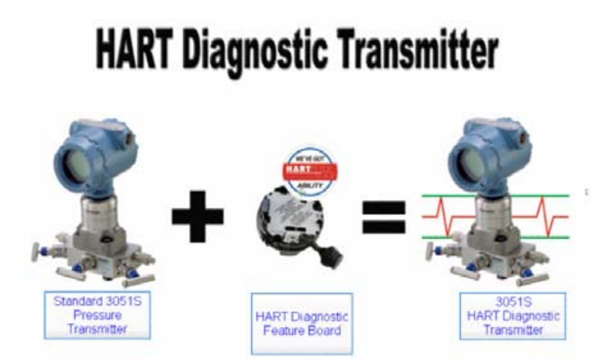

Figure 1: Architecture of 3051S HART Pressure Transmitter with Advanced Diagnostics

The high speed nature of the device and the internal calculation of the statistical parameters are key. Slower devices do not provide the necessary bandwidth to adequately capture the process or system's noise characteristics. As these devices are typically used for process control, some form of damping or filtering is typically employed either at the device or the Distributed Control System or PLC to provide a noise reduced signal for control purposes. This

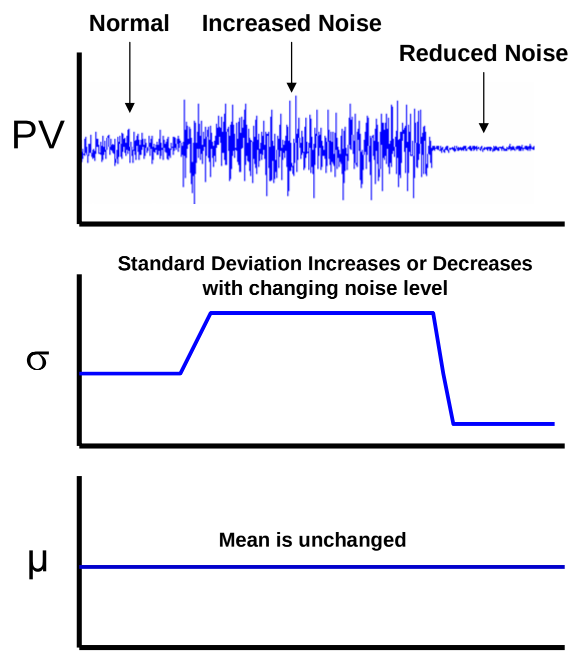

Figure 2: Effect of changing noise levels on the mean and standard deviation values for a process signal.

filtering or damping eliminates or sharply reduces the noise signal. In addition, computation of the statistical parameters at the system level is not practical due to the bandwidth limitations and sampling rates of a typical DCS or PLC. Most sample the signal at a rate of once per second or slower, considerably slower than the device samples its process variable (22 times per second for the 3051S Pressure Transmitter). The calculation of the statistical parameters within the device is

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accomplished on a parallel software path to that used to filter and compute the primary output signal (such as the 4 - 20 mA signal). The primary output signal is not affected in any way by this additional capability.

The device can provide the diagnostic information to the user in two ways. First, the statistical parameters can be made available to the host system via HART communication protocol. The system may make use of these statistical parameters to indicate or detect a change in process conditions. For example, the statistical values may be stored in the DCS historian. If a process upset occurs, these values can be examined to determine if changes in the values foreshadowed or indicated the process upset. The values can then be made available to the operator directly, or made available to alarm or alert software.

Second, the device has internal software that can be used to baseline the process noise or signature via a learning process. Once the learning process is completed, the device itself can detect significant changes in the noise or variation, and communicate the event via the LCD, an alarm via the 4 – 20 mA output and/or alert via HART.

Operation

A block diagram of the Statistical Process Monitoring (SPM) diagnostic is shown in Figure 3. The pressure process variable is input to a

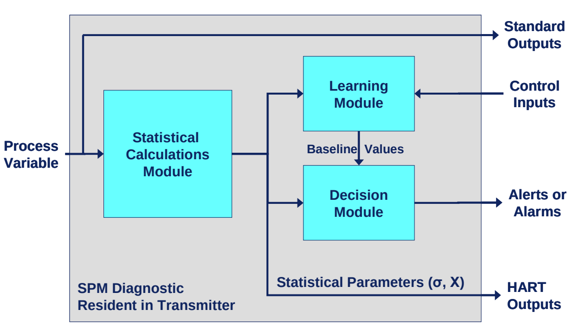

Figure 3: SPM block diagram

module where basic high pass filtering is performed on the pressure signal. The mean (or average) is calculated on the unfiltered pressure signal, the standard deviation calculated from the filtered pressure signal. These statistical values are available via HART and handheld communication devices like the 375 Field Communicator or asset management software like Emerson Process Management's AMS™ Device Manager. The values can also be assigned as non-primary variables from the device for communication to the user through other tools like the Rosemount 333 HART Tri-loop.

SPM also contains a learning module that establishes the baseline values for the process. Baseline values are established under user control via HART at conditions considered normal for the process and installation. These baseline values are made available to a decision module that compares the baseline values to the most current values of the mean and standard deviation. Based on sensitivity settings and actions selected by the user via the control input, the SPM diagnostic generates alarms, alerts, or takes other action when a significant change is detected in either value.

Further detail of the operation of the SPM diagnostic is shown in the Figure 4 flowchart. This is a simplified version showing operation using the default values. While the diagnostic continuously calculates the mean and standard deviation values, the learning and decision modules must be turned on to operate. Once enabled, SPM enters the learning/verification mode. The diagnostic calculates a baseline mean and standard deviation value over a period of time configured by the user (Learning/Monitoring Period; default is 3 minutes). The status of the diagnostic will be "Learning". A check is performed to make sure that the process has a sufficiently high noise or variability level (above the low level of internal noise inherent in the transmitter itself). If the level is too low, the diagnostic will continue to calculate baseline values until the criteria is satisfied (or turned off). After passing this check, a second set of values is calculated and compared to the original set to verify that the measured process is stable and repeatable. During this period, the diagnostic's mode will change to "Verifying". If the process is stable, the diagnostic will use the last set of values as baselines and move to the "Monitoring" mode. If the process is unstable, the diagnostic will continue to verify until stability is achieved. The stability criteria are also user defined.

Once in the "Monitoring" mode, new mean and standard deviation values are continuously calculated, with new values available every second. The mean value is compared to the

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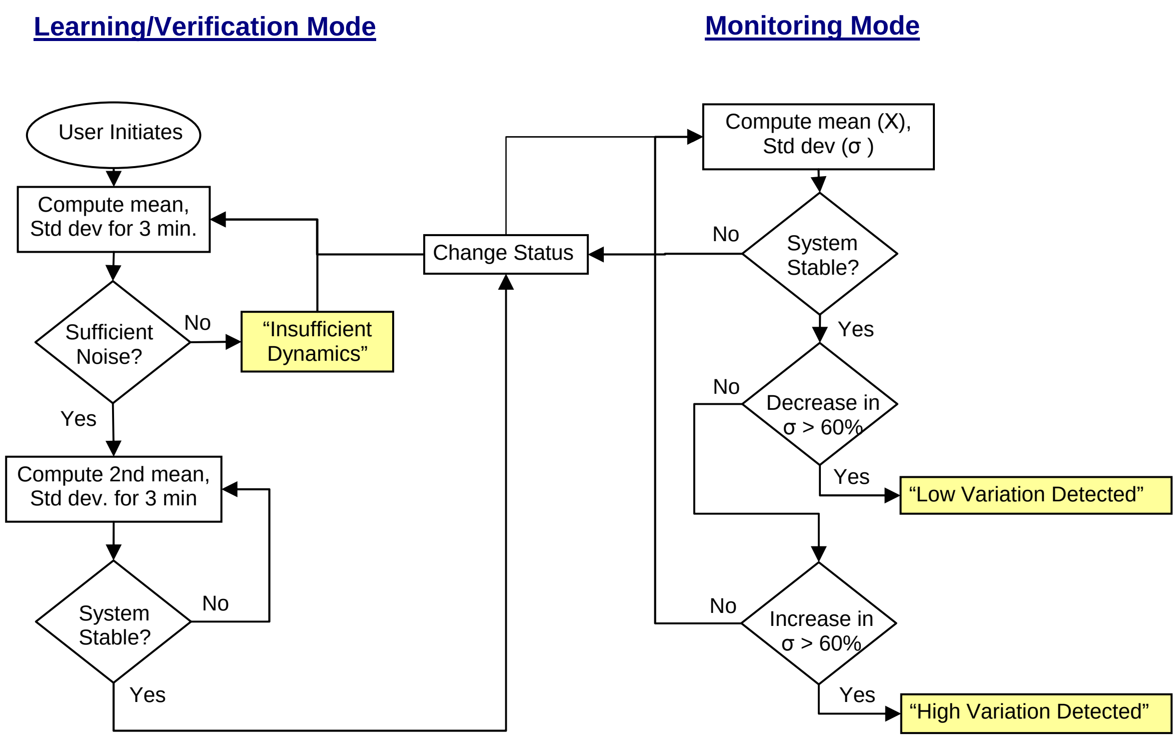

Figure 4: Simplified flowchart of SPM operation

baseline mean value. If the mean has changed by a significant amount, the diagnostic can automatically return to the Learn mode. The diagnostic does this because a significant change in mean is likely due to a change in process operation and can result in a significant change in noise level (i.e. standard deviation) as well. If the mean has not changed, the standard deviation value is compared to the baseline value. If the standard deviation has changed significantly relative to the baseline, exceeding preset sensitivity settings, this may indicate a change has occurred in the process, equipment, or transmitter installation and an alert is generated via HART.

When a trip of the diagnostic occurs, the event is also time stamped using the device's internal timer. This timer keeps track of the elapsed time since the event's occurrence, giving the user the ability to tie diagnostic indications from the 3051S to other events in the plant. The unit also uses the timer to record its total operating time. These time values are stored in non-volatile memory in the Diagnostics Feature Board.

The 3051S HART Pressure Transmitter with Advanced Diagnostics takes full advantage of the new Enhanced EDDL technology that enhances the user interface for hand held communicators and PC based and control system configurator products like Emerson Process Management's AMS Device Manager. The status screen from AMS™ Device Manager for the SPM diagnostic is shown in Figure 5. The charts display the most recent values of the mean and standard deviation with red lines, and also indicate the baseline (blue) and sensitivity values (grey) on the same chart. This screen also indicates if any alerts have been set, the mode of the diagnostic, and the time stamp value if an event has occurred. The diagnostic is also enabled/disabled from this screen, and an acknowledged event can be cleared with a "Reset" or "Reset and Relearn" command. Other configurable parameters are available on the other screens and are more fully described in the product's instruction manual.

SPM Application Examples

The SPM diagnostic may be applied to any pressure measurement. The SPM diagnostic is of most value in stable processes, where changes in noise or variability under static operating conditions may indicate that a significant change in the process, process equipment, or transmitter installation will occur or has occurred. (There may be value in its use

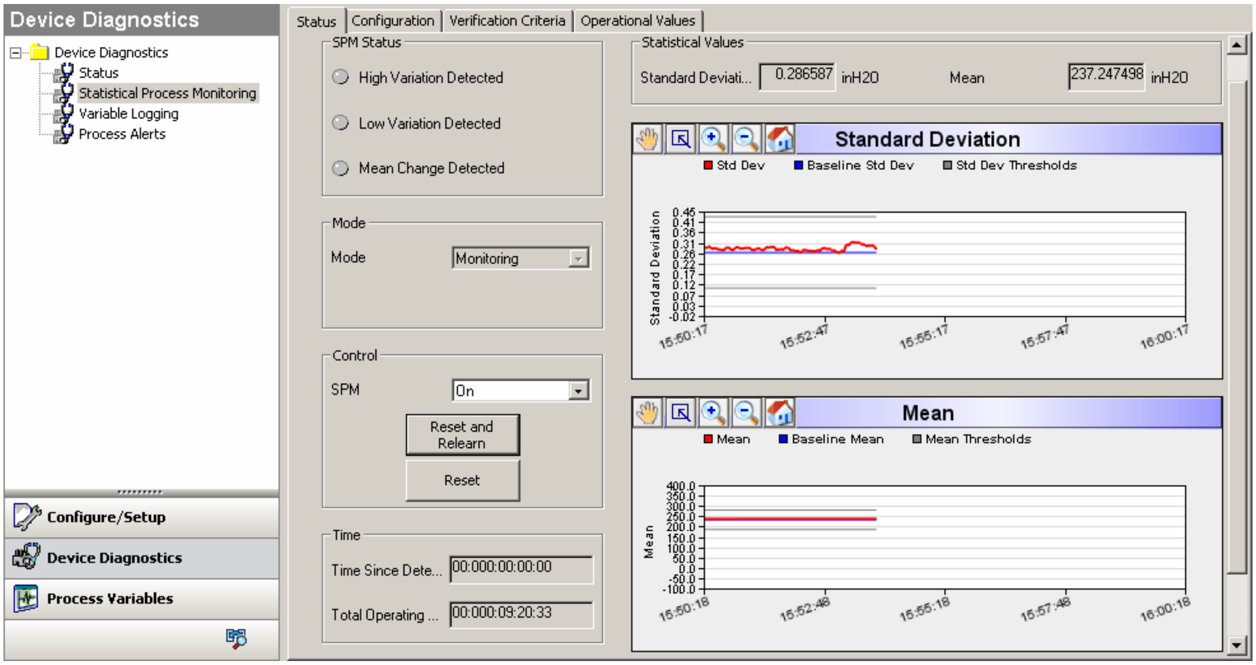

Figure 5: AMS Device Manager Enhanced EDDL SPM status screen.

even in static processes like level measurement, where a significant change in either mean or standard deviation may still indicate an issue of some kind.) Following are some examples:

Plugged Impulse Line Indication

Pressure transmitters are typically connected to the process via small diameter pipes called impulse lines. In some applications, these impulse lines can become plugged with solids or frozen in cold environments, effectively blocking the pressure signals. The user usually has no idea that this has occurred. This is because the pressure at the time of the plug is effectively trapped and the transmitter may continue to provide the same signal as before the plug. Only after the actual flow rate changes and the pressure transmitter's output remains the same may the plugging be recognized.

The SPM diagnostic can be configured to detect a plugged impulse line. Research indicates that in a typical flow application, the standard deviation at a given flow rate changes significantly if one (DP or AP/GP transmitters) or both impulse lines are plugged (Figure 6). The exact behavior depends on several factors, including the type of primary element, the length and condition of the impulse lines, and the degree of plugging.

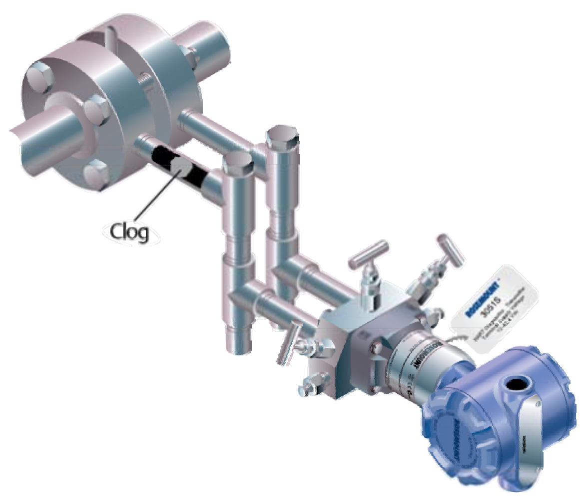

Figure 6: Diagram of Plugged Impulse Lines

Fluid Composition Change Detection

Research indicates that bi- or multi-phase flow conditions create significantly different noise patterns than single phase alone for a DP flow measurement, generally causing an increase in the standard deviation of the Differential Pressure signal. The SPM diagnostic could be used to detect significant amounts of liquid in a dry gas, or to detect a significant change in the liquid

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loading (Lockhart-Martinelli) of a wet gas. Testing indicates the same is true for liquid flows with significant amounts of air or gas entrainment.

Refinery Furnace Flame Instability Detection

Another example application of the SPM diagnostic is refinery furnace flame instability detection. Refinery furnaces often burn waste gases of varying BTU content. The BTU content may vary enough that the flame can become unstable, a precursor to flame out, a condition that the operator wishes to avoid. Tests were performed at a major furnace manufacturer. A flame instability condition was created (Figure 7). Through filtering and measurement of the noise content of the draft pressure transmitter monitoring firebox pressure, the unstable flame could be detected via the SPM diagnostic (Figure 8). Early detection before flame out provides the user with opportunities for corrective action.

Note: The Statistical Process Monitoring diagnostic capability in the Rosemount 3051S HART Pressure Transmitter calculates and detects significant changes in statistical parameters derived from the input pressure signal. These statistical parameters relate to the variability of and the noise signals present in the pressure signal. It is difficult to predict specifically which noise sources may be present in a given pressure measurement application, the specific influence of those noise sources on the statistical parameters, and the expected changes in the noise sources at any time. Therefore, Emerson Process Management cannot absolutely warrant or guarantee that the Statistical Process Monitoring diagnostics will accurately detect each specific condition under all circumstances.

Conclusion

Process, instrumentation, and maintenance engineers are faced with the challenges of reducing maintenance costs, improving quality, and increasing process uptime. Emerson Process Management now offers the ASP™ Diagnostic Suite on the Rosemount 3051S HART Pressure Transmitter. This suite includes advanced diagnostic capabilities, including Statistical Process Monitoring, that provides capability to help users focus on devices and equipment that need maintenance, identify devices and equipment that may be underperforming, and reduce process downtime.

Refinery Furnace

Firebox pressure signal

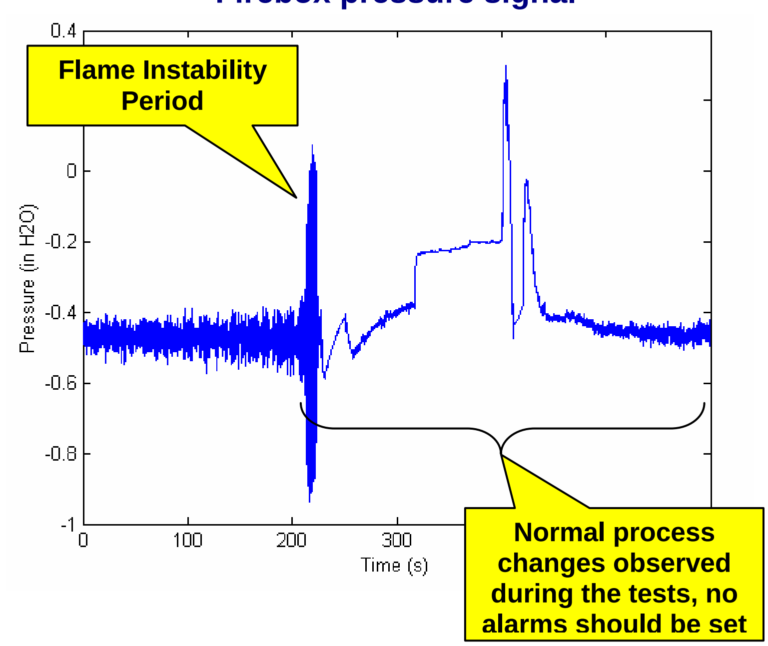

Figure 7: Refinery furnace and firebox pressure signal during tests, including period of flame instability

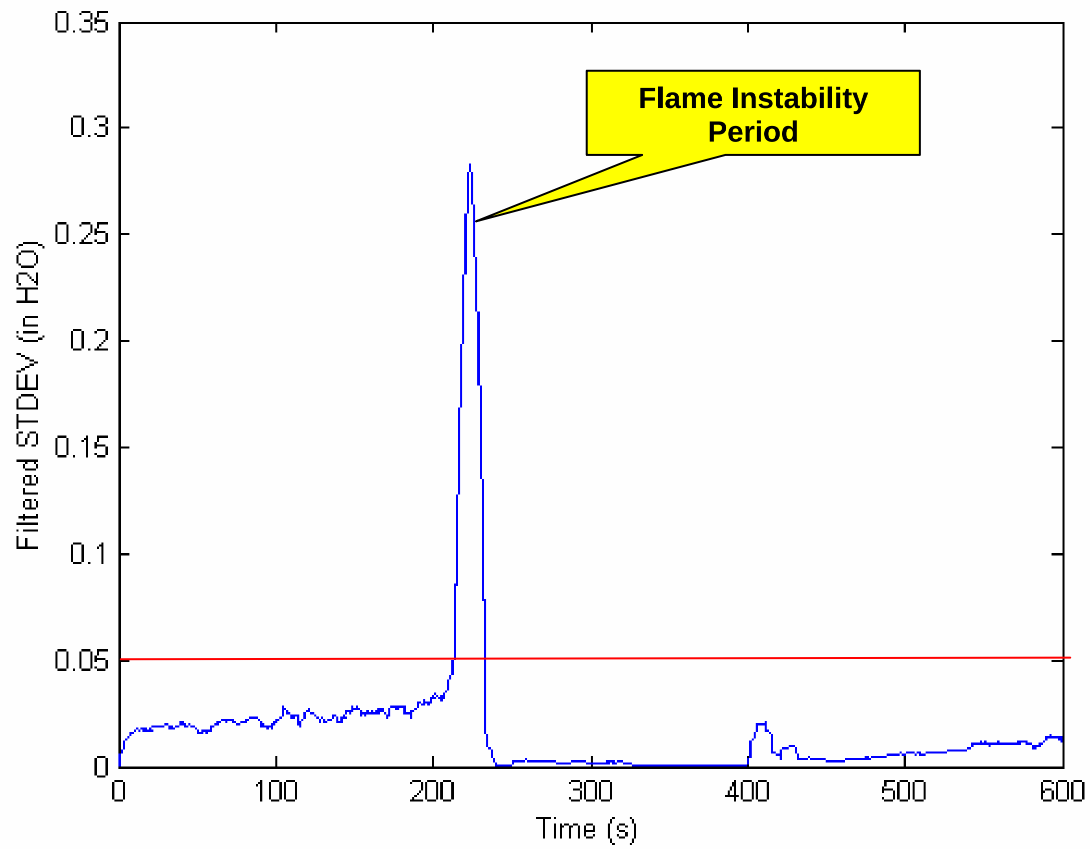

Figure 8: Standard deviation of Firebox draft pressure signal, after filtering in the 3051S HART Pressure Transmitter with Advanced Diagnostics.

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