Turning up the Heat

It's not often you hear about new advances in temperature measurement, but several underlying capabilities become possible with the application of hot technologies like fieldbus and EDDL.
By *Jonas Berge*.

Temperature sensors are in contact with the process, subject to high heat, vibration, corrosion, abrasion, pounding pressure, and stress from flowing fluids. Thermowells, when used, protect against some of these stressors, but not all. As a result, temperature sensors and their wiring are susceptible to degradation.

However, diagnostic technologies now allow plants to leverage thermocouple condition monitoring and failure prediction features that were previously unavailable in transmitters. Deployment of these technologies helps reduce process downtime and decrease energy costs. Specifically, the two open technologies brought together for detection, delivery and display of diagnostics are Foundation fieldbus and Electronic Device Description Language (EDDL).

Conventional two-wire, loop powered temperature transmitters with a 4-20 mA analog output have a power limitation as they must consume less than 4 mA. This limits processing power of the microprocessor, as well as the level of complexity of the device firmware.

In comparison, two-wire, bus powered fieldbus devices do not have this power limitation; a temperature transmitter can consume 12 mA or more, if need be. This enables the use of more powerful microprocessor, and subsequently more sophisticated device firmware, allowing for new powerful diagnostics.

As a further advantage, and unlike other communication protocols used in temperature transmitters, devices using Foundation fieldbus have a synchronized real-time clock that enables process and diagnostic alarms to be time-stamped in the transmitter.

The time-stamps allow event recordings to be accurate, even if the communication is not instantaneous. Alerts are sent when state changes. This is the most efficient use of communication, eliminating the need to wait for polling from the system.

Device diagnostics like those for thermocouple degradation, temperature tracking, and statistical process monitoring are prioritized and categorized as per NAMUR NE 107 recommendation. This allows the system to alert the right person without flooding others in alarms.

Making predictions

A thermocouple is made up by joining two wires of dissimilar materials in one end. A low voltage as a function of the temperature difference between the measuring junction and open end (cold junction) is generated, known as the Seebeck effect.

The transmitter measures the voltage at the open end, and computes the temperature from the voltage based on polynomials for each type of thermocouple. The temperature at the cold junction (transmitter terminals) must also be included, known as cold junction compensation.

Thermocouples are vulnerable to a number of failure risks. Wire thinning increases the resistance of thermocouples as does improper wiring connection at terminals. Over time, thermocouples may deteriorate, and burn out. If thermocouple conductors corrode, they also become brittle and may break due to vibration, particularly thermocouple types based on iron. The result of a degrading thermocouple or wiring is undesirable downtime.

Deterioration in thermocouples occurs slowly, and may cause inaccurate measurements. Thermocouple Degradation Diagnostic can help detect a failing thermocouple and allow preventive maintenance to be scheduled. Scheduled maintenance avoids the removal of a thermocouple from a process while in operation, which is not always possible.

Because thermocouple degradation is aggravated by long distances and multiple wiring terminations, field-mounted transmitters are preferred as a first step to reduce this problem. Next, thermocouple diagnostics may be used to monitor the health of the thermocouple. As thermocouples deteriorate, the resistance increases away from the baseline value that was recorded at installation. Thermocouple Degradation Diagnostic is able to measure and monitor the resistance of the thermocouple. If the resistance exceeds a threshold or "trigger" level, the operator will receive an alert. This alert will prompt the user to perform several preventive maintenance actions. The alert also allows time for a planned shutdown to be scheduled prior to a possible loop failure.

For many years, temperature transmitters have had diagnostics that, at time of sensor installation, are able to detect if sensor wiring is open or shorted. Temperature diagnostics have also provided the ability to detect if a sensor breaks and fails completely during operation. However, the ability to predict deterioration is new.

This is a good start, provided the diagnostics are passed to the operators so they can take evasive action. If a sensor breaks, the operator may have minutes or hours to respond before the process is affected. If device diagnostics are displayed on the operator consoles, operators can put loops in manual and take over control of the process. This is not ideal, since it may be strenuous on operators to run the process on manual for long periods of time, and control will not be as tight as during automatic control. Therefore predictive diagnostics is important.

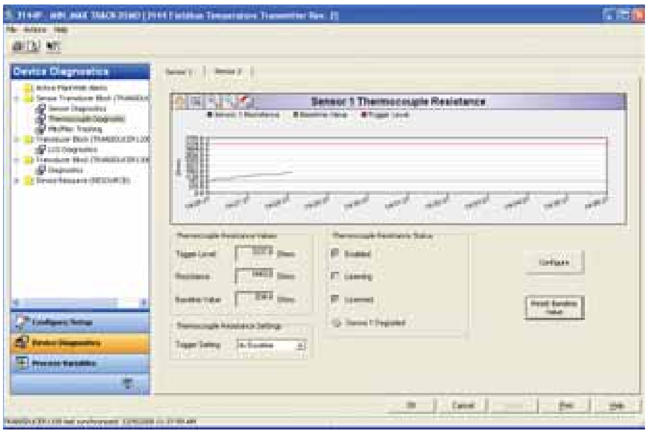
In some systems in the past, device diagnostics were either nonexistent or only displayed on a separate, usually unattended, maintenance station. This made the diagnostics less accessible and was not beneficial to operations. To make sure device diagnostics are incorporated into daily work processes, they must be displayed to operators at their consoles, integrated in accordance with NAMUR NE 91 recommendations.

The field diagnostics are prioritized based on the criticality of the device to the process and the severity of the fault in the device. This filters device alerts so that only those operation-critical ones reach the operators. It also eliminates alarm flooding in accordance with EEMUA recommendation 191. All device alerts, including predictive diagnostics not yet affecting the process, are reported to the maintenance console so maintenance may be scheduled for a convenient (later) time.

Using EDDL, the temperature transmitter manufacturer designs how the transmitter setup and diagnostics information shall be displayed in the device management software or handheld field communicator. This way, the transmitter manufacturer ensures the setup and interpretation of the temperature sensor diagnostics is as easy as possible for the user.

The multi-pen trend in the screen (overleaf) displays the thermocouple resistance, along with the baseline and trigger value. The trend plotted as a blue line allows any intermittent problems to be visualized, along with displaying the present resistance reading's distance from the trigger level.

Meanwhile, the thermocouple status is indicated by an LED mimic on the right side of the screen. The LED turns red if the ⇨



Diagnostics setup and result from the same screen using EDDL.

Dial indicators for visual display of transmitter temperature extremes.

trigger level is exceeded, indicating that preventive maintenance should be scheduled to inspect the thermocouple.

Replacing thermocouples during a planned maintenance period is easier, safer, and more cost effective than replacing thermocouples while the plant is running. As a result, downtime due to thermocouple failure and energy cost due to thermocouple degradation can be reduced. This translates into increased profitability, and in some cases, higher product quality.

The automatic testing provided by the Thermocouple Degradation Diagnostic feature also eliminates the need for periodic manual resistance testing, which may lower maintenance costs and cause less process disruption.

Transmitter temp check

Minimum and Maximum Temperature Tracking (Min/Max Tracking) continuously monitors temperature of the electronics (terminal) temperature, the two process sensors, and their differential.

A key application for the Min/Max Temperature Tracking feature is temperature monitoring of the transmitter itself. For transmitters mounted in close proximity to a process, heat from sources such as kilns, burners, boilers, etc can be transferred to the transmitter housing. At times, during certain combinations of process and ambient factors, the temperature of the transmitter's electronics may exceed the operating limit of the transmitter.

Although ambient temperature monitoring methods have existed in transmitters for two decades, many systems either did not support this communication, or the system tags were too expensive for secondary variable alarming.

Another application for the Min/Max Tracking feature aids in increasing yield and improving the product quality. An extreme spike or severe dip in temperature can alter the quality and yield of a product. Min/Max Temperature Tracking allows a user to identify if an unexpected product resulted from a spike or dip in process temperature.

By identifying the effect on a product due to changing temperatures, a user can recognize if it is necessary to keep a tighter control on process temperature. The extreme temperature values are recorded in transmitter with a date and time stamp, and remain until they are reset.

A major benefit of owning a control system based on Foundation fieldbus is that the closed-loop control is completely digital from sensor to valve. This digital infrastructure is used to deliver self-diagnostics from the transmitters to the operators and technicians if problems are detected, and detailed investigation can be done remotely.

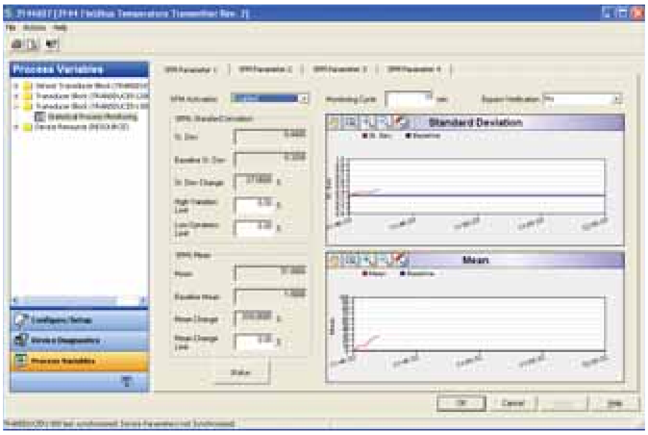
Because Foundation devices have an internal real-time clock kept synchronized with the system, the min and max temperature extremes are time-stamped, capturing the point in time when the temperature reached an extreme peak or experienced a severe dip, making it easier to correlate to external events to determine the root cause and eliminate the source.

If the identified source cannot be eliminated, consider use of additional thermowell extension length, an extension nipple, or a remote mounting configuration to isolate the transmitter from these excessive temperatures.

Tracking minimum and maximum temperatures in the transmitter instead of in the system reduces communication load, leaving bandwidth for faster real-time control. System tag count is reduced, and this lowers system cost.

Minimum and maximum values are best appreciated visually on a scale. Using EDDL, the device manufacturer can choose to have the values displayed in the system as a dial gauge, bar-graph, or other graphics element, whichever is the easiest to use for the customer. The Minimum and Maximum Temperature Tracking feature is user enabled, and the minimum and maximums temperatures may be reset together or individually.

Temperature transmitters operating within their ambient temperature limits perform better and last longer. Monitoring temperature peaks and dips in temperature may catch a process that needs tighter control. The result of minimum and maximum temperature tracking in difficult applications is improved process



Statistical process monitoring (SPM) is able to detect abnormal process behavior before operation constraints are reached.

performance and reduced downtime. With this feature, it is also possible to verify the temperature transmitter operates within hazardous area certification limits.

Process statistics

Apart from temperature element degradation, another plant challenge is detecting problems within the process. Today, some transmitters have sophisticated diagnostics able to detect abnormal process conditions in a wide variety of applications based on "statistical process monitoring".

Here, the sensor samples process temperature at high frequency and the transmitter internally computes statistical mean of the temperature and standard deviation of the process noise. For a significant change in noise without a change in process temperature, the transmitter alerts the technician to the impending problem. Noise is not just noise anymore; noise contains important process information.

Statistical process monitoring (SPM) is able to detect abnormal process behavior before operation constraints are reached, providing an early warning. SPM alerts provide process engineers with a better view of what is going on in the process.

Abnormal condition detection using statistical process monitoring may be used to detect hydrate formation in natural gas lines, scaling formation, and thermowell coating. Users are discovering and testing many new applications. The alerts provided by the transmitter, foundation fieldbus, and EDDL allow abnormal situation detection and prevention, and provide notification before a process is affected. Effective set up of statistical process monitoring is simplified by EDDL graphics designed by the device manufacturer and displayed on an EDDL-based system.

Because a distributed control systems (DCS) typically registers input updates once a second or slower, followed by damping to filter out the noise and transients, statistical analysis of noise or capturing intermittent events in system software is not effective. Data from plant historians is even less frequent. The statistical process monitoring and transient capture must be done close to the sensor to enjoy the necessary update rate, that is, inside the transmitter itself.

Boosting performance

These new diagnostics as described above are in addition to traditional sensor short- and open- circuit detection. Another diagnostic technology used to uncover a drifting or failing sensor is Sensor Drift Alert which detects errors in temperature sensors by comparing readings from two sensors measuring the same point.

Several underlying capabilities, such as time synchronization, time-stamped alerts, and device diagnostics integrated into operator stations, become possible when combining the power of Foundation fieldbus with the advantages of EDDL.

A digital infrastructure combining these two technologies allows you to take advantage of the latest developments in temperature measurement technology and new innovations that are not possible on an analog platform. It is the basis for a digital plant architecture that uses the power of field intelligence to improve plant performance. **CEA**

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