The Impact Of Instruments, Sensors, And Switches On Your Automation System

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Water and wastewater treatment is an automation-intensive process. With the rapid acceptance of Ethernet and increased reporting requirements, the use of automation will only increase. Thus, the need for repeatable, accurate, and reliable control has never been greater.

The precision and reliability of your control equipment relies on the accuracy of data coming in from sensors, switches, and other analytical instruments. Even with the highest quality-control hardware and program design, your automation system can fall short of expectations if it doesn't have the proper control system interface or if the sensing equipment is not properly selected, installed, applied, configured, and calibrated.

Proper Control System Interface

Sensing devices come in two general categories: on/off-based, otherwise known as discrete, and value-based, or analog. Discrete devices typically are easy to install and require little maintenance; however, their data-gathering capabilities are limited to either a yes or no scenario. Thus, many devices may be needed to get all the required data (e.g. four float switches in a wet well for sequenced pump control). This extra equipment can significantly add to installation costs.

Analog devices provide real value, but often have calibration requirements that require increased maintenance time. Some analog devices may come with contacts that can be programmed to provide a greater-than or less-than indication. Sometimes these contacts are connected to the programmable logic controller (PLC) instead of the actual value.

From a control standpoint, using the analog device's contacts instead of its value-based signal has three drawbacks. First, two conductors for each contact typically are required, which can increase installation costs. Second, the actual reading is not entered into the PLC; thus a human machine interface (HMI) or supervisory control and data acquisition (SCADA) system must show that a sensor is above or below a certain range — but not by how much. This can have a limiting impact for record keeping or troubleshooting. Third, changing the set points must be done at the sensor. This can involve navigating through complex menus. The net effect of these three drawbacks is that one operator at the SCADA control interface may assume the set point is at one value, while another operator has adjusted it at the transducer, resulting in operation problems.

In addition, network connections such as asynchronous serial interface (ASi), open controller area network (CANOpen), and Ethernet are gaining in popularity for interfacing sensors to PLCs. These network connections can gather vast amounts of data from both analog and discrete sensors while lowering installed costs. Each of these connection methods has its own benefits and drawbacks which must be considered during design.

Instrument Selection

Proper instrument selection is one of the most important criteria for control system accuracy. Price, long-term maintenance, reagent or chemical cost, and measured range are all criteria that need to be examined closely when choosing instruments.

Take dissolved oxygen probes as an example. For years, the predominant means of online (instantaneous) measurement has been through the use of probes based on the Clark principle. These probes use membranes and electrolytes as the main means of detection. They are maintenance intensive, and the frequency of maintenance is affected to a great degree by the composition of the process water. It is common for a plant to have to recalibrate, rebuild, or replace the probes every other month. This amount of maintenance can result in neglect due to fatigue. Without maintenance, errors creep into the control system and inefficient operation soon follows. This results in process upsets or wasted energy in the aeration system.

Recently, several companies have developed new luminescent probes. These probes do not have membranes or electrolytes, and they calibrate themselves just before they make a measurement. Therefore, they can automatically adjust for instrument drift over time. These differences can minimize the maintenance requirements experienced by traditional probes. On the downside, the luminescent probes are larger and more costly than the traditional probes. For dissolved oxygen, the right instrument choice depends on budget, staff commitment to performing long-term maintenance, and composition of the process water.

If the plant is a short-term installation or if dissolved oxygen is a noncritical criterion, then a lower-cost probe may offset the intensive maintenance requirements. If the sensor is a critical instrument for the plant, then luminescent sensors may be the right choice. Process specifics also may dictate which is better.

Installation And Application

Once an instrument is selected, great care must be taken to ensure proper installation. This is something commonly overlooked with flow meters. Most flow meters require laminar or nonturbulent flow for accuracy. Some flow meter technologies are more tolerant of turbulence. A good rule of thumb is that flow meters require straight pipe with no obstructions of 10 pipe diameters upstream and 5 downstream from the meter. For a 12-inch pipe, this means 120 inches of straight pipe upstream and 60 inches downstream are required. Flow straighteners may be used in some applications to decrease this distance. Some flow meters even require that a pipe be filled at all times.

Violating these guidelines can result in dramatic errors in the reading. A common misconception is assuming that these errors may be constant and one can adjust for them. While this is true to a certain extent, extremely turbulent water may give a wide range of readings that adjust as rapidly as 10 times a second. Although the PLC can detect signals that quickly, resolving them to a usable number can be difficult — if not impossible. The net effect is sabotage to the system's efficiency.

Another area where installation problems occur is with analytical instruments. Some online instruments, such as pH probes, can be destroyed if they are allowed to dry out. Furthermore, some instruments are susceptible to stray electric currents which can be caused by several factors, including your electrical system, chemical reactions, or from mixing action. Therefore it's important to ground variable frequency drives, motor shafts, tanks, etc. to minimize the effects of stray currents.

Some instruments employ automated processes such as titration, otherwise known as volumetric analysis, to determine the required parameter. These instruments take a sample, perform the analysis, and then discharge it. Some of these instruments have very tiny sample lines. To prevent blockage of the sample lines, a suitable filter may be required upstream of the actual instrument to filter out solids while allowing the desired material to pass through. If this isn't done, then the instrument won't get a representative sample, resulting in an erroneous reading that produces inaccurate control.

Before installing instrumentation products, it is also important to examine common assumptions made during the design phase. For example, it's generally assumed that coagulant introduced into a pipe will mix evenly with the process water. However, this isn't always the case. In one real-world application, the coagulant was being fed into the top of the pipe just upstream from a flow meter. Due to the meter's requirements, the flow was laminar and kept the coagulant pressed against the top of the pipe. This lack of mixing resulted in inaccurate control. This example can be explored to demonstrate the resulting effects of an inaccurate assumption.

INSTRUMENT CONFIGURATION CAN HAVE A DRAMATIC EFFECT ON A PLC-BASED CONTROL SYSTEM. FOR EXAMPLE, A MISCONFIGURED TURBIDIMETER INTERFACE COULD CAUSE A PERMIT COMPLIANCE ISSUE OR INEFFICIENT OPERATION.

In this example, a streaming current monitor is used to determine the dosing rate. As with any streaming current application, a time lag exists from the moment a chemical dosing change is made until the instrument detects the change. This lag time usually is short and, once complete, the new reading can be used to determine if further changes are required from the chemical pumping system. If the delay is too long, then it's difficult to achieve adequate control. In this example, the streaming current monitor sampling point is mounted on the side of the pipe. Since the coagulant is top-fed into laminar flow, the streaming current monitor does not get a representative mixed sample of coagulant, and the instrument can't generate a signal that's suitable for accurate control.

The most obvious solution is to move the sampling point to the top of the pipe. However, the streaming current monitor will sample water with a high concentration of unmixed coagulant, and the same control issues remain. Another option is to insert a static mixer in the pipe, forcing the coagulant and water to mix before entering the sampling pipe. However, the downside is the laminar flow requirements of the flow meter, and the cost of retrofitting equipment in use make this option prohibitive. Instead, another solution is to move the coagulant line to an upstream elbow or pump. These devices are more turbulent than a straight pipe and may allow for proper mixing. If there still is insufficient turbulence for proper mixing, the sampling port of the streaming current monitor can be moved to a downstream mixing tank. The water and coagulant will be properly mixed in the tank, and the meter will produce a signal that accurately reflects the chemical dosing rate. However, the distance from the coagulant injection port to the mixing tank and the length of the sampling hose from the tank to the instrument may cause a transit delay that prevents optimum performance. To overcome this, the coagulant feed can be moved to the mixing tank. This will eliminate the coagulant transit time from the point of injection to the mixing tank, and the remaining delay will be primarily a result of the distance from the sampling hose to the instrument. If this remaining delay still prevents accurate control, then another option would be to relocate the instrument closer to the mixing tank. This would minimize any remaining sampling transit delays. At this point, there should be proper mixing and minimized delay time resulting in acceptable control. This actual scenario demonstrates how assumptions can affect accurate control and how analysis of feed and measurement locations during design can eliminate potential commissioning delays and wasted resources.

Instrumentation placement also can be a critical factor during installation. For example, if aeration is supplied through a basin-wide diffuser grid, then it can be assumed that distribution of air is even across the basin. Any variance in dissolved oxygen can be attributed to process differences in a basin. This variation may require multiple probes in a large basin or just one in a smaller basin. Yet, the location for each probe is not critical as long as a representative sample of the tank's dissolved oxygen is acquired. However, in an oxidation ditch example with multiple rotors, even distribution is not assured. Thus placement of a probe just downstream of an operating rotor may give a false high reading. It may also give a false low reading when the rotor is not working. In this application, multiple probes and a voting scenario based on rotor operation may be required to achieve an accurate working average. Also, some systems may alternatively supply air to certain sections of a basin, while depriving other sections of air for denitrification purposes, making control routines necessary to accommodate an intermittent aeration scenario.

Equipment Configuration

The configuration of instrumentation equipment can affect the reliability of an automation system. In most instances, the equipment's reading scale should be somewhat larger than the maximum anticipated reading of the process. For instance, if a process is designed to operate between 40 and 70 degrees Fahrenheit, then a 0 to 100 degree range on the instruments and PLC may be acceptable. This allows the SCADA and PLC to respond to a reading in the unusual situation that it is outside of the design range.

Although the instrument's range should exceed the range of the process design, a balance must be maintained between resolution and maximum desired reading. In the above example, if the instrument range was -1000 to +1000 instead of 0 to 100, then a change from 70 degrees to 80 degrees would produce a miniscule change in the output signal, which may be difficult, if not impossible, for some PLCs to detect.

In addition, when establishing an instrument's scale, it is important that the PLC's scale can be adjusted through the operator interface. This allows the operator to ensure the PLC system matches the instrument without requiring programming software.

Furthermore, custom configurations may need to be developed to ensure proper operation. For example, if a level is used to determine flow over a weir and the weir doesn't resemble any of the standard profiles programmed into the instrument, then the reading will be inaccurate. Therefore, levels will need to be gathered manually for several specific flows across the entire flow range, and this data can be used to build a table inside the instrument or a PLC. Then the instrument can be configured to take an actual reading that corresponds with an approximate flow based on the table.

Optimum Operation

As outlined, instruments and their selection, installation, application, configuration, and calibration can have a dramatic effect on a PLC-based control system. The overall effectiveness of the control system can be sacrificed if the instruments are not carefully examined during all phases. Only when all of these factors are properly addressed can the control system hope to achieve its optimum state of operation.

About The Author

Grant Van Hemert is an automation and control applications engineer for the Schneider Electric Water Wastewater Competency Center. Mr. Van Hemert has 11 years of water and wastewater experience. Previously, he was a design and implementation engineer, where he designed and commissioned automation and instrumentation systems dealing with aeration, screening, and clarification. ●