PRACTICAL AUTOMATION FOR FACILITIES ENGINEERS

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ABSTRACT
Automation is a crucial element for modern production facilities in the Permian Basin. This paper will discuss automation and instrumentation basics as part of a broad automation philosophy to help readers understand how individual components fit into a complete design. Individual components (or instruments) will be examined to share what options are available to industry and how they can best be utilized. An analysis of four common field development scenarios will help facilities engineers grow their knowledge and be better prepared to implement automation in their facilities.

INTRODUCTION

A methodical approach to automating a production facility will help today's facilities engineer in the Permian Basin. An automated system utilizes instruments to measure a variable and cause a change to be made through a control device based on the gathered information. There are many positive reasons to automate a production facility: alarms to alert personnel in the event of an undesired facility condition, control devices that automatically react based on certain conditions, safety devices that will disable or shutdown equipment if control is lost, the ability to view the facility via smart phone or computer, and the list goes on. Drawbacks to automating a facility can include: expensive installation and maintenance, lack of knowledge in the workforce to install or maintain, incorrect designs that lead to upsets and frustration, a reliance of the workforce on the automation and not on their intuition, and this list could go on as well. By building an understanding of what tools are available and how to implement them, facilities engineers will be able to successfully apply their knowledge to the benefit of their company.

THEORY

Point Measurement vs Continuous Measurement – Point Measurement and Continuous Measurement are rather intuitive based on their names; point measurement is measuring a variable in a control system for when a specific point is met, and continuous measurement is measuring a variable in a control system without seeking any particular point. Point measurement instruments are commonly referred to as 'switches' because once a specific point is met for the variable, one action occurs. For example, think of a porch light with an automatic, self-contained switch. When the sun starts going down, the sensor measures that it is getting darker, but only when it gets dark enough for the specific point of the sensor does it trip the switch for the light to come on. It cannot tell you what the variable was reading other than it met the specific point, and it cannot do anything else other than turn the light on. Continuous measurement instruments are commonly referred to as 'transmitters' because they are only capable of transmitting the value of the variable that they are sensing. They need some sort of computer with logic in order for the control system to react. For example, think of the same porch light but this time with a transmitter. When the sun starts going down, the sensor will send constant readings of how dark it is to some sort of computer. The computer could be programmed to turn the light slowly on as it gets darker, like a dimming feature. This would be beneficial as it makes sure the porch has a constant level of light through the day and into the night, and not just all of the sudden have the light turn on.

Digital (discrete) Signal vs Analog (continuous) Signal – The method that an automated system receives or sends a signal could be digital, analog, and sometimes both. Digital Signals relay data as quickly as a system can capture a data point and place it into the data stream. While this may not be perfect, it may suffice for the demands of the system. Data points are easily analyzed as they are discrete values (precise and time bound). Analog Signals are continuous in that there are no breaks in data transmission. Every data point conceivably recordable is present in the data stream. This could cause data to be difficult to process or analyze[1], especially if digital control is desired. Figure 1 at the end of the paper shows the difference in how a control system might view a digital and analog signal.

Direct Sensing vs Indirect Sensing – From an automation standpoint, there can be more than one option or method used to achieve a desired measurement in a controlled system. No matter what the method is, the instrument selected for the task will either be Direct Sensing or Indirect Sensing. Direct Sensing instruments will take a real measurement of a variable and transmit it back to the system as an actual value – no conversion needed. For example, consider a radar sensor that has been installed in the top of an oil tank. The radar will send a pulse into the tank and set a timer for how long it takes for the pulse to reflect off the surface of the oil and return. The measured time will be converted (using the speed of sound) into a direct measurement of how far the oil level is away from the top of the tank. The radar will transmit this value to the system as a direct tank level measurement. Indirect Sensing instruments will take a measurement of a separate variable in the system (that might have nothing to do with the desired variable to be measured) and transmit this value back to the system where it will be converted into usable information. For example, consider the same oil tank as above but with a pressure transmitter connected at the bottom of the tank. The pressure transmitter will continuously read how much pressure is acting on it (in this case, how much hydrostatic head from the oil), and relay this pressure measurement to the system. The system will already have the density of the oil programmed into it, and will back-calculate the pressure measurement into a fluid column height. The system now has as the indirect tank level measurement.

<u>INSTRUMENTS</u>

Level Measurement – The level of a fluid in a tank can be measured using a wide array of instruments. Level switches will only indicate to the system when the level has reached a specific point – this is particularly useful for high level alarms, or low level shutdowns, for example. Instrument choices for level switches include both direct sensing and indirect sensing devices, and are described below:

- Float Switch – direct sensing – a mechanical float will sit idle and dry until the fluid rises and reaches the float. The float will rise with the level of the fluid. When the float reaches its set point, the mechanical linkage on the switch will indicate the condition is met, and a signal will be sent to the system.
- Vibration Tuning Fork – direct sensing – a tuning fork will be vibrating continuously at a known frequency. When the fluid rises and contacts the tuning fork, the frequency will be adversely affected because of interference and friction caused by the fluid. The switch will recognize that the known frequency is no longer being met and a signal will be sent to the system.
- Head Switch – indirect sensing – a pressure transmitter will be connected near the bottom of the tank to continuously read the hydrostatic head and relay it back to the system. The system will calculate what the level is based on a predetermined fluid density, and will trigger a signal when the level exceeds the desired value[3].
- Murphy Switch – indirect sensing – a tubing line will be connected near the bottom of the tank to the sensing side of the Murphy switch. As the level in the tank rises, hydrostatic pressure rises, and the Murphy switch will react to the pressure with its bourdon tube or bellow by turning a gauge needle. When the gauge needle meets a mechanical set point, an electrical connection is made that sends a signal to the system[4].

Level transmitters will measure level continuously, and can feed this reading back to the system however often the system desires it. There are many instruments to choose from, with a select few described below:

- Magnetic Float – direct sensing – a tube (that is appropriately matched to the pressure inside the tank or vessel) will be attached to the vessel just like a sight glass (open nozzles on the top and bottom). A float with a magnetic charge will rest inside this tube, and rise or fall with the level in the vessel. A magnetic readout on the outside of the tube will be attracted to float on the inside of the tube and indicate precisely where the level is. This is useful in applications where low pressure sight glasses may not be desirable.
- Radar or Ultrasonic – direct sensing – both sensors will send a pulse (radar uses electromagnetic waves, ultrasonic uses sound waves) inside the tank or vessel, and count how long it takes for the pulse to reflect off the surface of the fluid and return back to the sensor. The speeds of each

pulse are known which allows the sensor to calculate how far away the level is from the sensor. This value is transmitted to the system where it is translated into a level in the tank or vessel[5].
- Differential Pressure – indirect sensing – this is much like the head switch from above, except more of the functionality of the pressure transmitter is used in relaying continuous streams of information instead of hunting for the one desired level set point to trip an event in the system.

Pressure Measurement – The number of instruments available in pressure measurement are not near as plentiful as level measurement. Pressure switches are not dynamic in that they can only send one signal or cause one event when the set point pressure is met. This is desirable for high and low pressure shutdowns in a system. Two such instruments are described below:
- Pressure Switch – direct sensing – a pressure switch is essentially the same as a head switch mentioned above.
- Murphy Switch – indirect sensing – a Murphy switch in a pressure application will work exactly the same as described in the Level Measurement portion of this paper. This would be used to shut down an element of the system or send an alarm if the (high/low) pressure set point was met.

Pressure transmitters are more functional than pressure switches in that information can be relayed back to the system as often as desired. This is necessary for trending variables to understand how a process is behaving. One such instrument is described below:
- Pressure Transducer – direct sensing – an impervious, protective diaphragm is exposed to the process in order to sense the pressure within the system. As pressure is applied to the diaphragm, an electrical signal will be produced linearly with the pressure. The transducer will correlate this signal into a pressure reading and relay it back to the system for action, if any[6].

Flow Measurement – Flow switches are simple in nature and rely heavily on mechanical components to indicate that a set point has been met. They are desired in cases where equipment or the environment needs protection, for instance when a pump needs a high-flow shutdown when a line might have developed a substantial leak. One such flow switch is described below:
- Paddle Switch – direct sensing – a paddle is pre-sized for fluid properties and maximum flow desired. The paddle is installed inside of the meter housing in the direct path of flow. It is connected to a sort of mechanical linkage limit switch, and as flow increases through the meter, the paddle will raise inside because of the flow’s force acting on the paddle by the fluid. When the linkage hits full open (as indicated by the paddle reaching its maximum flow design) a signal is sent to the system that the set point has been met.

Flow transmitters on the other hand, can be quite complex in nature and extremely accurate in volume and/or mass flow. Each type of flow meter will take readings in their own way and relay back to the system for computing. Selection of the flow meter will depend on the application, capital budget and maintenance demands tolerated by the operator:
- Volume Type – direct sensing – a positive displacement meter will work much like a positive displacement pump. Rotary vanes move within a tight-tolerance housing with a known volume. Each rotation will register in the system a precise amount of volume moved through the meter and will read back to the system. These meters are relatively inexpensive, relatively easy to maintain, the rotary vanes have a relatively decent life expectancy as long as there are no solids being pushed through the meter.
- Velocity Type – direct sensing – a turbine meter operates off of a propeller type element directly in the stream of fluid flow. As it spins, a magnetic pickup will count how many rotations the propeller is making and correlate a flow rate. These meters are cheap, they do not tolerate solids or any sort of trash which can make them troublesome (the propeller element is relatively expensive compared to the cost of the entire meter if it is damaged, but is simple to replace in the field), and in clean service the life expectancy is relatively long.
- Mass Type – direct sensing – a Coriolis meter is the most scientific meter of the ones described in this section. Internally, there are bent tubes that the flow is directed through. A vibrating element will cause the tubes to oscillate at a baseline frequency, and an accelerometer will pick up the frequency at which the system is responding. As fluid passes through the bent tubes, the frequency changes and the resultant reading is correlated to a flow rate. The meter uses a mass reading for its calculations and translates this into volume flow by a simple conversion with known

fluid properties. These meters are relatively expensive (but preferred in custody measurement because of their accuracy), they can tolerate relatively more trash and debris, and the life expectancy is very long because of very few moving parts.

MAKING IT ALL WORK

The heart and soul of an automated system is the Programmable Logic Controller (PLC). A PLC is a computer that is used to interpret data from a system and issues commands based on that data to control the system. The main components of a common oilfield PLC are the rack, power supply, central processing unit and input/output area. The latter logic program is written and stored in the memory of the PLC[7]. A PLC cannot perform its important job without being connected to all of the instruments and control devices. This is not trivial in nature; a facilities engineer is faced with hard decisions that are completely situational.

Wired – an automated system should be hard wired in situations where there are not many devices or when the facility has little potential for expansion or upgrade. The largest expense is purchasing and installing the conduit (ditching as necessary) and purchasing and installing the paired wires. The two variations of a wired system are Parallel Interface and Serial Interface. In a Parallel Interface, each instrument or control device in the automated system has a designated wire pair connected to the PLC. When the PLC needs information or needs to send out a command, it communicates directly through this wire pair to the desired device. In a Serial Interface, instruments and control devices are wired directly together or through main cables back to the PLC. When the PLC needs information or needs to send out a command, it will broadcast a specific, coded signal to all instruments. Only one instrument or device is programmed to receive this unique code and will broadcast back to the PLC with its response.

Wireless – an automated system should be wireless in situations where installing conduit would be cost prohibitive or when future expansion of the facility is inevitable. A wireless system cuts out the conduit and associated work, but adds the expense of wireless transmitters and battery replacement. Installation could be considered faster, which might make this option attractive in a tight project schedule. The two variations of a wireless system are Parallel Interface and Serial Interface. In a Parallel Interface, each instrument or control device in the automated system has a radio transmitter and a specific radio address. When the PLC needs information or needs to send out a command, it communicates directly to this specific radio address of the desired device. In a Serial Interface, instruments and control devices are still required to have a radio transmitter and a specific radio address. When the PLC needs information or needs to send out a command, it will broadcast a specific, coded radio signal to all instruments. Only one instrument or device is programmed to receive this unique code, and will broadcast a radio signal back to the PLC with its response[8].

FIELD DEVELOPMENT SCENARIOS

In a greenfield development scenario where there is tight facility spacing, it may be most appropriate to install a wired system with individual pair wires. Expense installing conduit would appear to be low, given the tight spacing, and any upgrades in the future should also be relatively close to existing conduit.

In a greenfield development scenario where there is plenty of real estate, it may be most appropriate to install a wireless system. It is a good practice to space out a facility to make room for maintenance, which ends up inflating the cost to install conduit between the far reaching ends of the facility.

In a brownfield development scenario where there is a new infill drilling program and no existing automation, it may be appropriate to install a wireless or a wired system. If there is uncertainty about what is buried beneath the facility, it may not be the best move to start ditching. If there is confidence in what lies beneath the surface, then it would work best to install conduit with enough capacity to tie in upgraded equipment associated with the infill wells. If the infill drilling program has an uncertain number of wells in the future, it may be difficult to predict the size of conduit needed.

In a brownfield development scenario where an automated retrofit is needed because of remoteness, a wireless approach might work best to reduce installation cost. Bolt-on wireless transmitters could be a quick and easy solution to gain the surveillance desired to reduce operator time spent traveling to and from this facility.

CONCLUSION

This paper described how a proper, methodical approach to automation can help today's facilities engineers in the Permian Basin. There are many positive reasons to automate a production facility, but they must outweigh the negatives. Knowing what instruments are available and how they function will help facilities engineers make more informed decisions about choosing to use or not use automation.

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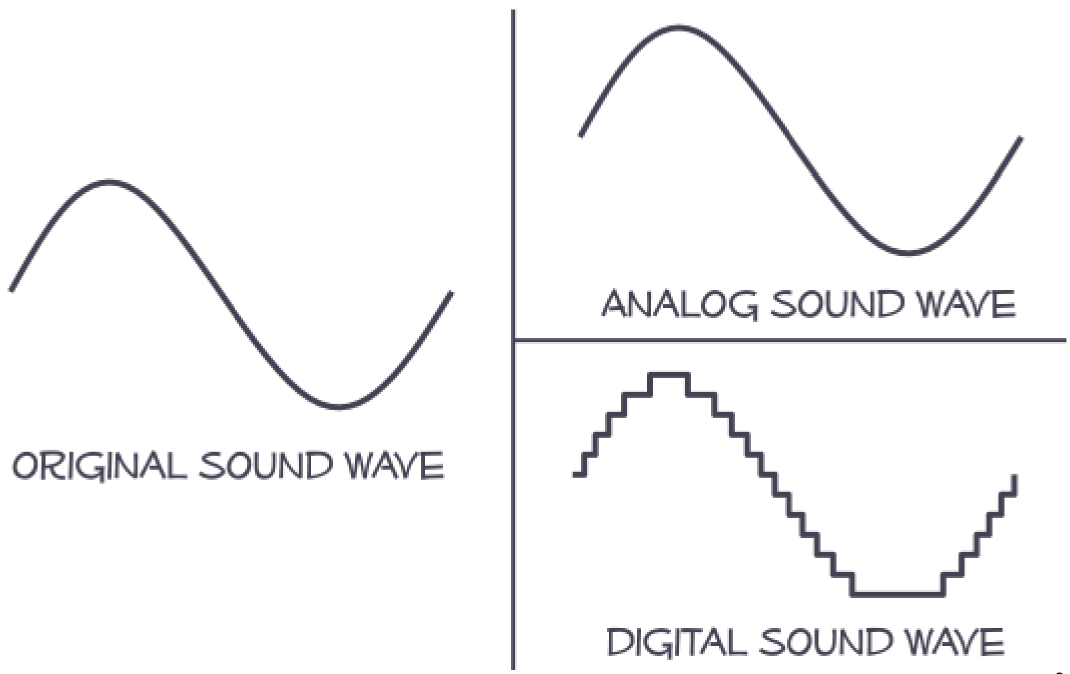

Figure 1 - Differences between Digital (discrete) and Analog (continuous) Signals[2].