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Advances in Process Automation Computing Platform

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ABSTRACT
The landscape of computing platform for process automation has changed over a period. Proprietary hardware and software dominated the process automation field for last three decades. This paper talks about how the hardware and software for process automation industry evolved and the latest trends in each layer of the process automation computing platform.
Keywords- Industrial Automation, Process Automation, Process Control, DCS, PLC, SIS, HMI, Virtual Machines

I. INTRODUCTION

Industrial Automation is a vast field. It includes manufacturing automation, process automation, transfer line automation and other miscellaneous applications. The manufacturing automation involves automating the work typically with the help of robotic arms and tools. Both manufacturing automation and assembly line automation is typically found in industry that make widgets such as cars, phones, toys, beverages etc.Process automation usually deals with automation in the process industry such as refineries, petrochemical plants, chemical & pharmaceutical industry. Usually one never sees the raw material or the finished product that is made in the process plants. The raw material is brought in through pipelines and may be stored for a short time in closed metal containers. The reactions and purification processes occur inside the thick walled reactors, distillation columns, absorption towers and various other process equipment. The finished product is transferred from the plant through pipeline or closed containers. These materials could be flammable, highly toxic, poisonous, and hence they are contained in the vessels and/or pipelines. The only way to measure the process values is by sensing devices. While the evolution of hardware and software platform has occurred in all the sectors of industrial automation, the focus of this discussion is primarily on the computing platforms used in the process automation industry.

II. PROCESS AUTOMATION SYSTEM

Figure 1 shows generic system architecture of today's process automation system. It consists of four layers.

A. Field Instruments

It includes all the instrumentation including analytical systems for continuous measurement of process values such as temperature, pressure, flow, level, current, composition etc. It also includes the final control elements that regulate the process such as regulating valves, on/off valves, dampers, variable speed drives, motor control etc. The measurement devices provide input signals to the controllers. The final control elements receive the output signals from the controllers. The input and Output signals are analog or discrete. Analog signals are for continuous process measurement or valve opening. 4-20 mA is the industry standard for the analog signals that represent 0-100% of the measurement range. Discrete signals indicate status such as motor run status. The discrete signals use variety of voltages including AC and DC. The more recent trend is to use 24VDC circuits for the discrete signals and use interposing relays where different voltages are required.

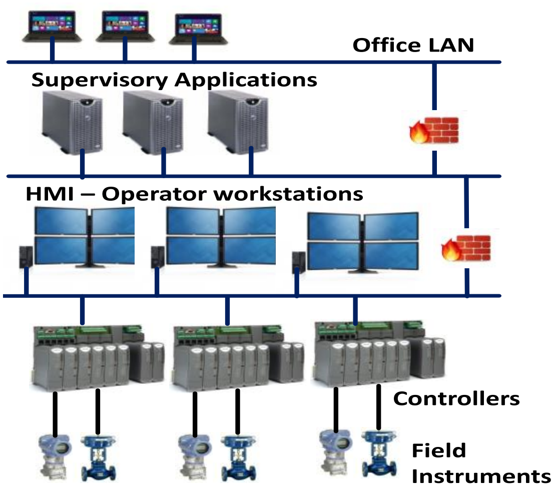

Fig.1 Generic Process Automation System Architecture

B. Logic solvers and Controllers

These devices are the core of the process control system where the most Basic Process Control functions are executed. The field instruments are wired to the Input/Output cards of the controllers. The input card scans all the connected inputs, performs Analog to Digital conversion and other signal processing such as noise filtering, square root of the measurement for flow signals and store the values in memory registers. In the process automation industry, each measurement or a memory register is called "tag". The CPU of the controller executes the basic control functions such as PID (Proportional Integral Derivative) control, algebraic calculations such as ratio or Boolean logic. The calculated outputs are written through the output cards to operate the final control elements.

C. Human Machine Interface

HMI provides the window to the process. The operator can view and interact with the process through graphic displays on the operator workstations.

D. Advanced/Supervisory Applications

There are number of supervisory applications that run in the layer above the Basic Process control. Some applications such as multivariable process control and real time optimizers write values to the controllers providing optimized set points to the control loop. The data monitoring and reconciliation applications read the values from the controllers and perform business functions and calculation including statistical data analysis. Process data historians, reporting and metrics calculations, billing and production planning applications are some examples.

III. COMPUTING PLATFORMS

A. Field Instruments

These devices are at the beginning and at the end of the process automation loop.Process measurement is the first step in process automation. There will be a probe such as thermocouple for temperature measurement or orifice plate for flow measurement. A sensing device that converts the process signal (pressure, millivolts, current) to digital format is part of the transmitter.Transmitters have evolved from early days of pneumatic – electric – electronic – microprocessor based. In last 10 years with faster processing capabilities, the transmitters and valves have become very function rich. One such example of using advanced processing power in transmitter is the plugged impulse line detection. The pressure, flow and level transmitters use line pressure or differential pressure to measure the respective process value.

The tube that connects the transmitter to the process pipe or a vessel is called impulse line. The impulse line is small in diameter and can easily get plugged due to the solids in the process fluids or due to freezing (Fig 2a). The operator usually doesn't know that the blockage has occurred. The pressure at the time of plug is trapped and the transmitter continues to provide the same signal as before the plug. When the actual process value changes, the transmitters still shows the same constant measurement which is misleading to the operator. This can result into unsafe situation and may potentially lead to an accident. Using the advanced processing technology, it is possible to detect the plugged impulse line. All dynamic processes have a unique noise. The reason it is called noise because it is a nuisance or of no value to understand the process measurement such as pressure, flow or level. However, this noise is of tremendous value as long as it can be measured using high speed sensing device. The process noise has unique signature. The signature can be measured and stored using statistical tools when the impulse line is clean. The mean and standard deviation of the stored healthy noise signal can be compared to the current value. As the impulse line gets plugged, the noise signature changes.

Fig. 2a Plugged Impulse line detection

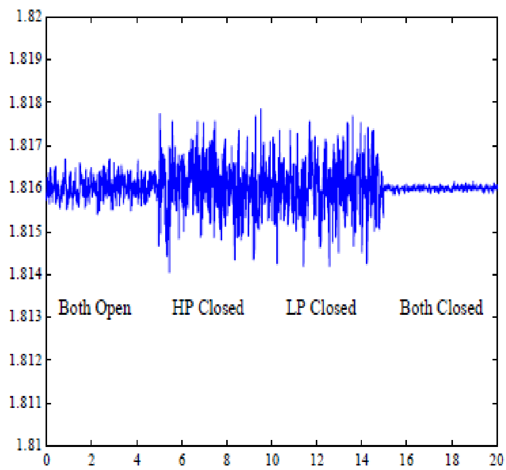

Fig. 2b Noise signature of the process

Figure 2b shows a plot of noise level in different conditions. The differential pressure transmitter used for flow or level measurement has two legs. One on high pressure side (upstream of the orifice plate) and the other on low pressure side (downstream of orifice plate). When both the impulse lines are clean, a common mode noise is generated. If any one of the impulse lines is closed or plugged, the common mode cancellation of noise does not occur and there is increase in noise of the signal. When both the lines are closed, the noise dies down significantly.Each process measurement has a unique signature and typically at the time of commissioning, the healthy signatures are stored by the engineers in the respective transmitters.

B. Logic solvers

The logic solvers are considered the brain of the control system. Logic solver is a generic term and performs three main functions

- Reads the inputs from process measurement transmitters.
- Performs the logic operation, calculations, executes programs etc.
- Writes the outputs to the final control elements

In the past, main frame computers were the logic solvers. All the inputs and outputs of the entire plant were read by the mainframe computer. The same computer processed all the algorithms, performed calculations and then wrote outputs to the final control elements. The terminals attached to the mainframe were the human machine interface to the process. Due to the reliability, maintainability, cost and scalability reasons, this type of architecture was soon replaced by distributed architecture where the logic solver function was distributed among different hardware devices called controllers and the controllers communicated over network. Specialized hardware and software devices evolved such as controller, operator station, engineering station, historian and hence the system is called "Distributed Control System (DCS)" as the functionality is distributed over various specialized devices.

In the process industry, there is large number of analog or continuous signals such as pressure, temperature, flow, level, motor current etc. The processing at controllers is accomplished using standard function blocks as PID controller, ratio, summation, low/high selector, two out of three selector etc. The control of the process happens mostly with analog output signals that regulate a valve – which in turn controls the amount of feed or fuel or steam etc. used in the process.

The manufacturing industry differs from process industry primarily in the types of signals. In manufacturing automation, the signals are primarily discrete. Limit switches, solenoid valves, and proximity sensors that control the robotic arms or movement of conveyors in an assembly line operation. The process is highly logic or sequence driven and hence the Programmable Logic Controllers (PLCs) are more predominantly used in this industry. The requirements for robustness and reliability are different. Failure of any component in the automation loop in manufacturing industry will result into product loss, some capital damage and disruption to the assembly line for some time. Failure of a component in automation loop (sensor – logic solver – valve) in process industry may develop a hazardous situation that lead to catastrophic accident, fire, explosion, loss of life. For this reason, in process industry, there are separate Safety Instrumented Systems (SIS) independent of the Basic Process Control System (BPCS) that offer an additional layer of protection. The reliability and robustness requirements in process industry are lot more stringent than other industries.

The controller where most control algorithm processing takes place is still a proprietary device. The manufacturers of the controller use their own hardware, operating system, hardware design. Even today, there is no such open hardware platform like we have in computers and laptops for the controller hardware and software. The users do not have access to the operating system software. The access is only at application level to configure the functionality. Conceptually, everything that the controller performs can be done in a generic computer. However, because of the security, reliability and performance requirements, no one uses general purpose computers to control the processes such as refineries, petrochemical plants.With the faster processors and development in computing technology, these controllers have become very feature rich. The controllers in 80s were very basic. They would read 16 or 32 signals, execute algorithms such as PID control and write the outputs to final control devices such as valves.Today the controllers can read and process 200 – 500 IOs, execute sequential logic and user written programs in higher level programming languages. Although the programming languages are still tightly controlled by the system vendors, they closely resemble the higher level programming languages like C# or visual basic.

C. HMI

The next important element or layer above controllers in a DCS is Human Machine Interface (HMI) or operator work stations. Operators monitor and control the plant through graphic displays, historical process value trend displays and variety of specialized displays that presents the real time process information in most meaningful way to the operator. Most suppliers of DCS use generic hardware platforms such as Dell or HP machines, windows operating system but a proprietary layer of application software that communicates with the controllers. When the mainframe terminals were replaced by individual workstations in distributed architecture for HMI, there used to be one machine for every screen. Typical operator console has between four to twelve screens and that many work stations. With better processors and video cards now one workstation can very easily drive upto four monitors. There are at least two workstations in an operator console to make sure that the view to the process is not lost with the loss of one of the workstations.

D. Supervisory Applications

The layer above the HMI in a process automation system is the supervisory applications layer which does variety of computations and data archiving functions such as

- Advanced Process Control (APC) or Multivariable Predictive Control (MPC)
- Real Time Optimization (RTO) to maximize the profit or minimize the energy consumption
- Process Data Historian
- Terminal Server
- Billing / custody transfer applications

PID algorithm in DCS controller regulates single loop (e.g. flow loop). It reads the flow measurement, calculates the output to adjust the valve opening to bring the flow to its desired set point. The flow loop doesn't know how the changes will affect the line pressure, outlet temperature, levels etc. A reactor or distillation column or a reformer in the hydrocarbon processing industry has more than a dozen such control loops and several more measurements. MPC has a process model and understands the interaction of all these variables. MPC provides the set points for multiple single loop controllers at the same time to optimize the production and to reduce the energy consumption. The MPC algorithms have high computational requirement with matrix operations running in real time. MPC does not directly take part in regulatory control. It is supervisory in nature. The failure of MPC does not cause production disruption or safety issues. The productivity of the plant may suffer when the MPC application is not running. Due to less reliability requirement but high computational needs, MPC algorithms are executed in a separated dedicated high end machines. It usually requires a separate server (such as OPC server) to enable the data exchange and operator interaction with the DCS. Each vendor with supervisory control or business function usually insists on having a separate dedicated machine for their application. The number of physical machines adds up. A refinery unit with approx. 2000 IOs can very easily have 50 or more workstations, servers and controllers as part of the process automation system.

Significant changes and improvements have occurred in the hardware platform used for supervisory functions. One of the most significant improvements is the use of virtualization to combine various servers into one physical server. The recent release of Windows 2012 server has accelerated this change. Windows Server 2012 Standard edition gives the purchaser the rights to run 2 virtual instances of Windows Server [2]. So, theoretically, the number of supervisory machines can be reduced by at least half without paying for additional licensing. There are several other benefits of running the applications in virtual machines such as ease of redeployment, backups, maintenance, cluster configuration. Windows 2012 server uses Hyper-V technology, first introduced in server 2008 and then progressively improved in each subsequent release.

IV. CONCLUSIONS

Advances in computing technologies have enabled remarkable improvements in each layer of the process automation system. The filed instruments have become smart and more reliable improving the quality of control and process safety. Controllers continue to get increasingly powerful in terms of their processing capabilities and the redundancy options and hence fewer controllers can do much better job than their predecessors. Controllers are still highly protected proprietary devices. In the modern DCS, the number of operator workstations have reduced as one workstation can drive two to four screens. The workstations use the generic hardware platform and predominantly the windows Operating system.

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