How Advanced Process Control Lowers Cost and Enhances Industrial Production Efficiency

by Ritesh Agarwal

Executive summary

Industries lose millions of euros each year because of process inconsistencies and poor control systems performance. With minor investment, these losses are avoidable. Recent technology advancements in advanced process control (APC) systems enable industrial sites to save on energy and raw materials while improving product quality and plant profitability. This paper describes methods for leveraging new advanced process control techniques.

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Introduction

As industrial sites continue to evolve in complexity while attempting to fulfill demands for increased production output, plant operators are in a bind as they cannot monitor all the variations happening in thousands of process control loops. In most plants, more than 75% of plant assets are employed in manufacturing. The majority of these assets are under process control. If not optimized, these assets are not fully productive and therefore inefficient.

The problem is that traditional control systems don't provide a systematic way of monitoring, diagnosing, and improving process control performance. According to the journal *Control Engineering,* only 1/3 of control loops in a typical plant are performing at acceptable or better performance (see **Figure 1**). Therefore, 2/3 of control loops need urgent improvement.[1] (Note that in **Figure 1**, an "open loop" refers to a system that is basically manual with very few automatic control or feedback features built in to regulate a process variable so as to maintain the desired output level or value.)

Through proper process control and optimization, most plants have the potential to increase profit by hundreds to thousands of euros per shift. In most cases a minimal investment can produce impressive results. By implementing advanced control tools and mechanisms, operating costs can be cut anywhere from 2 to 6%.[2] Commercial control loop monitoring software, for example, is capable of collecting and analyzing massive amounts of loop data from which to identify opportunities for improvement.

Collectively, these industrial process efficiency improvements are referred to as advanced process control (APC). These improvements are enabled by tools such as distributed control systems (DCS) that optimize processes so that plant equipment is performing at full potential with process control loops properly tuned. This paper explains how APC works and describes how processes are optimized and how performance is monitored and maintained using DCS tools.

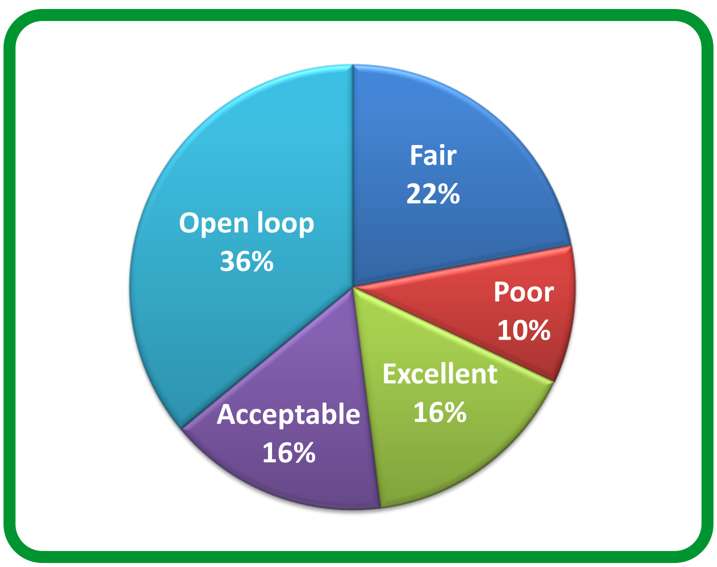

Figure 1
Industrial sites have room for improvement as only 1/3 of process control loops are performing at an "acceptable" or better level

How APC works

Advanced process control (APC) is an umbrella term that can apply to many different types of implementations in factory environments. Examples include implementation of feed-forward or cascade control schemes, of time-delay compensators, of supervisory, inferential,

[1] VanDoren, Vance, Ph.D., P.E. "Advances in Control Loop Optimization Control Engineering", *Control Engineering*, May 2008

[2] Anderson, J.S. (1992). 'Process control opportunities and benefits analysis'. Proc. Advanced Control for the Process Industries, Cambridge, 9-11th Sept.

multivariable, non-linear and model predictive processes, and of self-tuning or adaptive algorithms. The purpose of APC is to deliver sustainable, measurable benefits by stabilizing a manufacturing plant in order to produce a consistent yield of quality products.

In a typical plant, 80-85% of control loops are linear with processes that are relatively simple to control. However, the remaining 15-20% of controls is complex and requires more advanced forms of control in order to operate in a cost-effective, efficient manner. The linear processes are often managed via proportional-integral-derivation (PID) controllers. These are control loops with feedback mechanisms that calculate an error value (difference between the measured process variable and a desired set point). An example of a PID controller application would be a simple level control loop in a water tank. PID controllers are effective for those processes that do not have any noise or loop constraints (see **Figure 2**).

The limitation of PID control is that it is characterized by a feedback system, with constant parameters, and no direct knowledge of the process, and thus overall performance is reactive and a compromise. This is why PID cannot provide adequate control for non-linear processes (like HVAC systems, glass furnace level controls, and heat exchangers, to name a few).

With more complex processes, challenges such as large numbers of constraints, unknown disturbance sensitivities, complex process responses, and limitations in measurements require control beyond the ability of PID controllers. In these cases, APC can be used to achieve accurate control, fast response, and process and energy optimization.

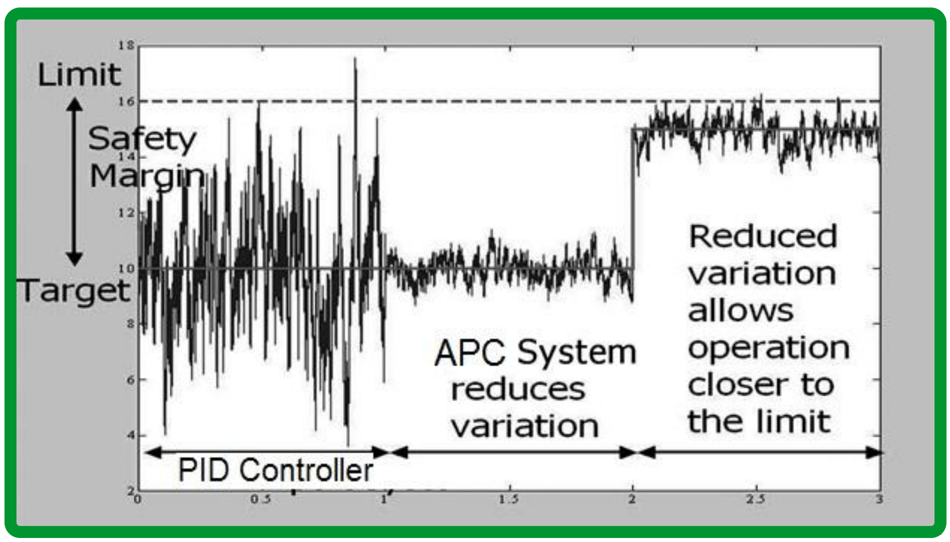

Figure 2
The precision of an APC approach allows processes to operate at significantly higher levels of efficiency

Figure 2[3] is an example of a steam turbine in which raising the temperature increases the steam pressure and, therefore, improves turbine efficiency. In steam turbines, the temperature rise is a sluggish process. If a PID controller is used to control the temperature, the perturbation will be greater and thus the target temperature set point must be fixed far from the maximum allowed temperature limit (i.e., the maximum temperature threshold capacity of the turbine) so as to have a safety margin[4] to avoid damaging the turbine. So in this case, turbine efficiency will be reduced.

But if an APC system is applied (i.e., a predictive controller is used to control the steam turbine temperature), the perturbation will be much less and the target temperature set point

3 *Minerals & Metals Review* – December 2013 Edition
4 Safety margin is the difference between maximum allowed temperature limit and the target temperature set point.

can be put very close to the maximum allowed temperature limit. Using an APC system to control the steam turbine temperature increases turbine efficiency and optimizes the process.

Depending upon the needs of the particular process being optimized and to enable broad application across multiple manufacturing environments, APC implementations approach complex process control challenges in a number of different ways. Common APC approaches include model-based predictive control (MBPC), extension of PID control, multi-variable control, and “fuzzy” control.

Model-based predictive control (MBPC)

Model-based predictive control uses a reference model of the process to predict future process behavior and calculates an optimum set of control moves that minimize the deviations from the desired control objective. This approach is often used in sluggish, non-linear processes that have loop constraints and overshoot limitations. Examples include glass furnace level control, heat exchange, and cement kiln temperature control. This predictive capability allows the controller to determine the best way to adjust the process. The controller manipulates the input variables to drive process output variables to their optimum targets while considering interactions and remaining within any imposed constraint specifications.

The use of a process model is what differentiates MBPC from other APC technologies. Examples of the type of software that exploits the MBPC approach include data mining, modeling, and tuning tools. The model-based control algorithms of the software are applied to simple and integrated processes with feed-forward compensation, zone control functions, and intelligent ramp functions.

Multi-variable control

Most industrial processes require control over several variables. Systems with more than one control loop are known as multi-input / multi-output (MIMO) or multi-variable systems. Examples of multi-variable control applications include a distillation column and a chemical reactor. In the instance of a chemical reactor, the variables of interest are the product composition and the temperature of the reaction mass. In such a system there are two control loops: a composition control loop and a temperature control loop.

Feed to the reactor is normally used to manipulate the product composition, while temperature is controlled by adding or removing the energy from the reaction via heating / cooling coils. A change in feed to bring product composition to its desired level would change the temperature of the desired mass. On the other hand, removal or addition of heat would determine the rate of reaction which, in turn, influences product composition. **Figure 3** provides an illustration of this concept and is a classic example of 2x2 multi-variable control.

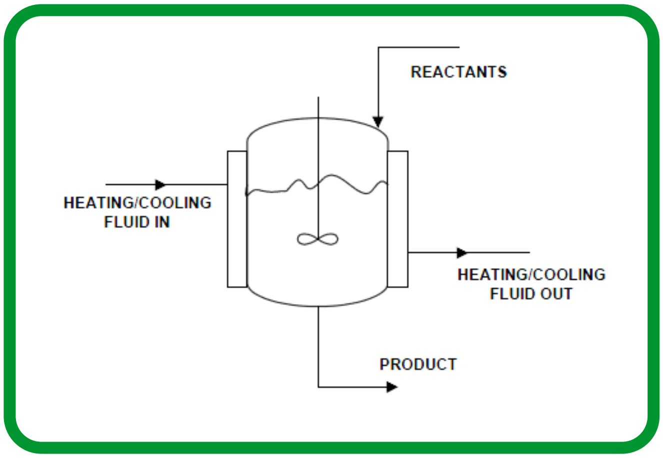

Figure 3
Illustration of a chemical reactor that operates within the constraints of two control loops, one for temperature and one for product composition

Extension of PID control

Extensions to existing PID controls can also enable development of an advanced process control approach to manufacturing production efficiency. A standard PID controller relies on feedback logic. That is to say, feedback control can act only on the result of a disturbance, which means feedback control cannot execute an action until the process variable has been affected by the disturbance.

For example, outlet temperature of a heat exchanger can be measured and used for feedback control. The feedback controller manipulates the steam flow to the heat exchanger and keeps the outlet temperature as close to the set point as possible.

An extension of PID control implies an improvement to incorporate feed-forward control, which, in contrast to feedback, acts the moment a disturbance occurs, without having to wait for a deviation in a process variable. In such a scenario, the advanced process extensions take care of major disturbances, and the standard PID controller takes care of more minor process variables that deviate from pre-configured set points. Again using the example of a heat exchanger, when major disturbances arise from changes in the process flow rate, advanced process control is used to measure and proportionally adjust the steam flow rate. PIDs can be enhanced in additional ways such as improving measurement (i.e., higher sampling rate, and precision, accuracy, and low-pass filtering) and adaptively altering modifications based on performance.

The tuning of control loops is also an operations problem that can be addressed by PID extensions. The traditional approach is to utilize a trial-and-error method to tune the loop. New PID extensions allow for automatic tuning, which saves operators time and helps to improve precision.

Fuzzy control

Another APC technique, called "fuzzy control" is based on the principle of fuzzy logic. Fuzzy logic imparts a unique intelligence to machines, enabling them to reason in a non-precise, intuition-like manner similar in some ways to humans. A fuzzy control tool deals with uncertain, imprecise, or qualitative decision-making problems. Embedded fuzzy controllers automate what has traditionally been a human control activity. **Figure 4** illustrates a typical interface for a user working with a fuzzy control design tool.

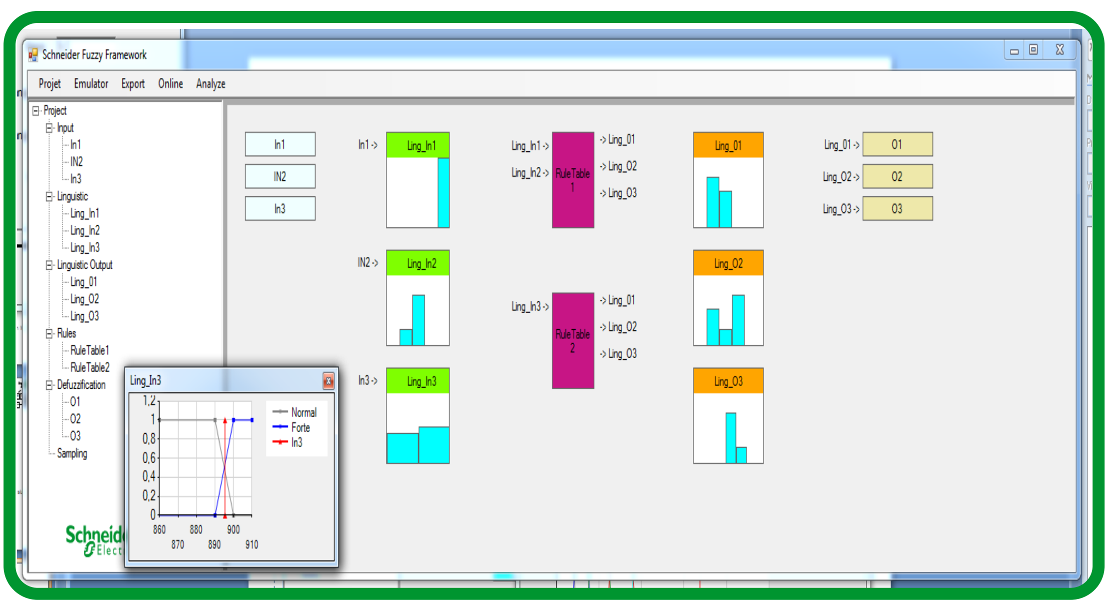

Figure 4
Example of a Schneider Electric fuzzy control design tool

Fuzzy logic is well suited, for example, to the non-linear world of chemical process control. Control statements are developed in terms of imprecise rules relating the values of measured variables with planned adjustments of the manipulated variables. This control methodology relies on knowledge in the form of rules that describe system behavior. These rules and their associated membership functions must be developed from knowledge of process behavior.

The output of the fuzzy logic controller is determined by a process called defuzzification. This process converts the output of the associated rules into a single numerical value that is denormalized and then used to control the manipulated variable.

This APC approach is widely used in machine control. The US Environmental Protection Agency, for example, has investigated fuzzy control for energy-efficient motors, and NASA has studied fuzzy control for automated space docking. Simulations show that a fuzzy control system can greatly reduce fuel consumption. Fuzzy control also applies itself well to HVAC control systems, and machine operation within the water and wastewater segment.

Fuzzy design tools in the marketplace generally provide the following services:

- Fuzzy logic creation
- Simulation for testing
- Derived function block generation services
- SCADA interface creation
- Online visualization

Conclusion

Most manufacturers have yet to fully leverage their investment in plant equipment through process optimization. Plant assets need to perform at full potential in order for industrial businesses to remain competitive. For plant equipment to perform at maximum efficiency, process loops need to be tuned properly. In addition, performance monitoring needs to ensure that process improvements are both achieved and maintained.

Over the past several years, advanced process control (APC) technologies have endured and survived growing pains, and have now reached a stable state of maturity. Such technologies have become a differentiating factor as factories worldwide become more digitized and less mechanical. APC is a powerful tool that can stabilize plant operations, reduce losses, maximize throughput, improve product quality, and minimize energy consumption.

Enhanced production efficiency and reduced downtime can be achieved with distributed control systems (DCS) that are capable of supporting advanced process control functions and techniques.

About the author

Ritesh Agarwal is a Manager — Advanced & Segment Libraries at Schneider Electric's Plant Automation Solutions & Libraries (R&D) in Bangalore. He is also Group Edison Expert Level-1 in Schneider Electric and member of "Cross BU Technical Experts Community" called G4 Community in Schneider Electric India. He holds a Bachelor of Technology (B.Tech) degree in Instrumentation & Control Engineering from the JSS Academy of Technical Education in Noida, India. He has 11 years of experience in the field of system architecture design, industrial process automation, advanced process control solutions & optimization. He has also filed 4 patents in the Mining Minerals Metals segment for Schneider Electric. He has worked with some of the most reputable and largest automation system providers in the world, in the oil & gas, steel, glass and electro-graphite industries.