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Air Separation Advances With Model-Free Adaptive Control

Houston-Based Air Liquide America Realized Rapid ROI and Almost Instantaneous Improvements in Quality and Production

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ASUs have numerous process variations, depending on parameters such as customer quality requirements and the product's primary use (i.e., merchant, pipeline, or on-site tonnage). Air Liquide defined these control objectives for ASUs:

* Improve product quality: Maintain nitrogen and oxygen products on specification and minimize the waste nitrogen purity and crude argon impurities.
* Maximize product yield: Maximize product recovery from the incoming air feed.
* Stabilize the process: Adjust process conditions to maintain the unit operation within process and equipment constraint limits, and minimize transient disturbances when the unit is being ramped to new feed or product targets.
* Maximize feed throughput: Maximize feed rate subject to equipment limits and product quality specifications. In the market-limited case, the dry airflow (feed) and product flow are maintained at their desired targets.

Control Problem

The specific goal of this application was to control the rich liquid reflux level in the high-pressure cryogenic column so it would remain as constant as possible, even during plant ramping and upsets where this level typically is affected. The rich liquid reflux flow to the low-pressure cryogenic column is used to manipulate the high-pressure column rich liquid reflux level.

It is difficult to control the high-pressure column level by manipulating the reflux flow using a PID controller. Overly tight control will result in large oscillations in the reflux flow, which causes a lower product yield. PID control is usually detuned to allow the level to fluctuate to minimize variations in the reflux. However, this may result in safety problems when a large plant upset occurs. In addition, large oscillations can cause the whole process to swing, which also results in a lower product yield.

It is difficult to properly tune a PID controller for optimal control under all conditions due to the variable rates of the high-pressure column inflows/outflows, so an adaptive controller was sought.

Solution: Model-Free Adaptive Control

Air Liquide's Chicago Research Center has performed extensive laboratory tests involving different advanced control products including the ones with model predictive control (MPC) and model-based adaptive control techniques. The patented CyboCon model-free adaptive controller, developed by Rancho Cordova, Calif.-based CyboSoft, General Cybernation Group, has consistently ranked among the top performers in laboratory tests and simulations. This controller, one of the first plug-and-play control products on the market, has proven effective in laboratory tests and easy to implement and to adjust online. Good results were achieved in controlling single-input, single-output loops (SISO), as well as multiple-input multiple-output loops (MIMO).

Air Liquide currently implements multivariable predictive control (MVPC) for plantwide optimization and is looking for MFA controllers to assist with difficult, hard-to-tune regulatory (SISO) loops that could bring significant benefits with adaptive control.

MFA controls complex processes and has certain defining characteristics:

* Precise quantitative knowledge of the process is not necessary.
* No process identification mechanism is needed.
* No controller design for a specific process is required.
* Complicated manual tuning is not required.
* Closed-loop system stability analysis and criteria are available to ensure system stability.

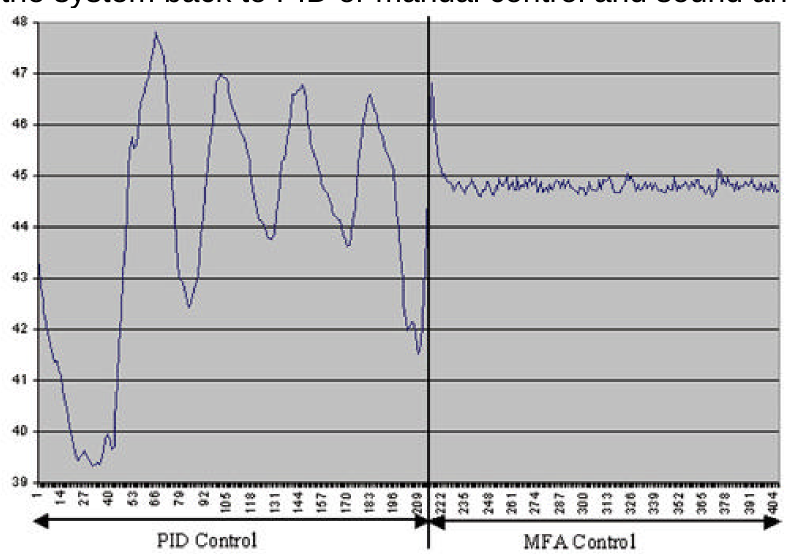
Installation and Operation

An MFA controller was installed to control a high-pressure column of an air separation unit at Air Liquide's Burlington, Wis., plant. The results were very encouraging and quickly achieved, which soon led to another installation of the same type of controller for the same application in the company's McMinnville, Ore., plant.

At each plant installation, CyboCon software was installed in a PC running Windows NT. The MFA controller was easily configured and launched after the communication was established between the PC and the DCS via Dynamic Data Exchange (DDE).

In contrast to PID control, the MFA controller was able to provide tighter control so that the overall process ran more smoothly. More importantly, the MFA controller does not over-manipulate the reflux to achieve this goal. It provides an intelligent control output so that both ends of the process move smoothly, resulting in well-balanced material flow. This contributed to an immediate improvement in the process operation and a higher product yield.

The MFA controller can be easily placed in automatic or manual mode from either the CyboCon screen or the DCS screen. For safety reasons, the MFA controller sends a heartbeat signal indicating whether the connection between the PC and DCS system is on or off. If the heartbeat signal is lost, the DCS will switch the system back to PID or manual control and sound an alarm to operators.



Graphic Results of MFA and PID Control

Selected actual plant data trends from the Burlington air separation unit MFA implementation clearly show the advantage of new MFA vs. the old PID level control (Figure 2).

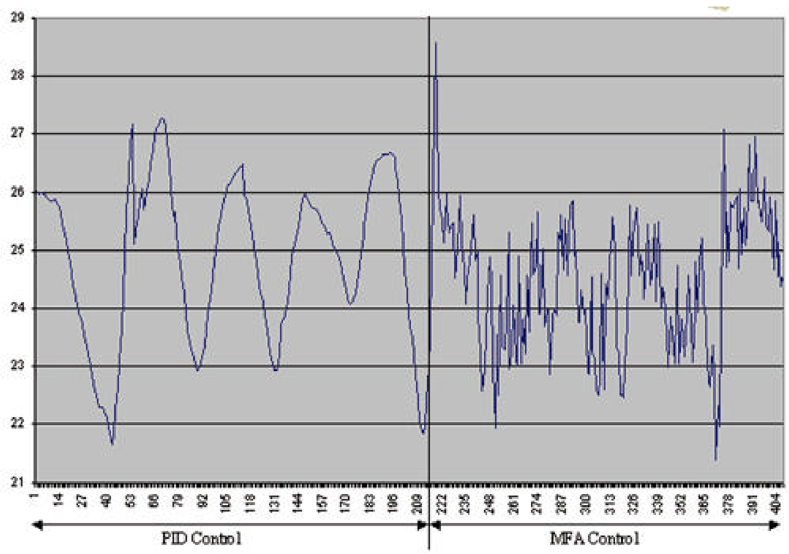


Figure 3 shows the rich liquid reflux flow manipulated by PID and MFA. The MFA output moves with a faster and more intelligent pattern that actually reduces overall variation of the reflux flow. Notice that the frequency is greater in MFA, but the magnitude is similar or perhaps less.

Figure 4 indicates principal column purity. An immediate improvement of production was achieved after the MFA controller was launched.

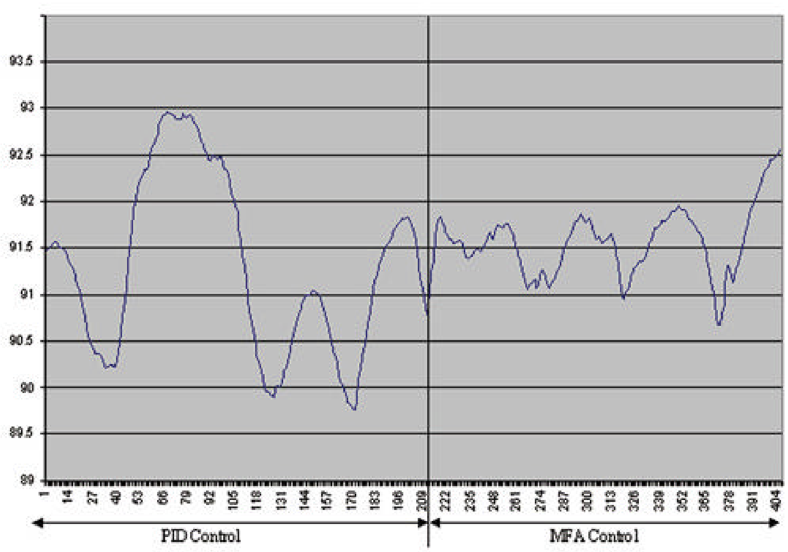
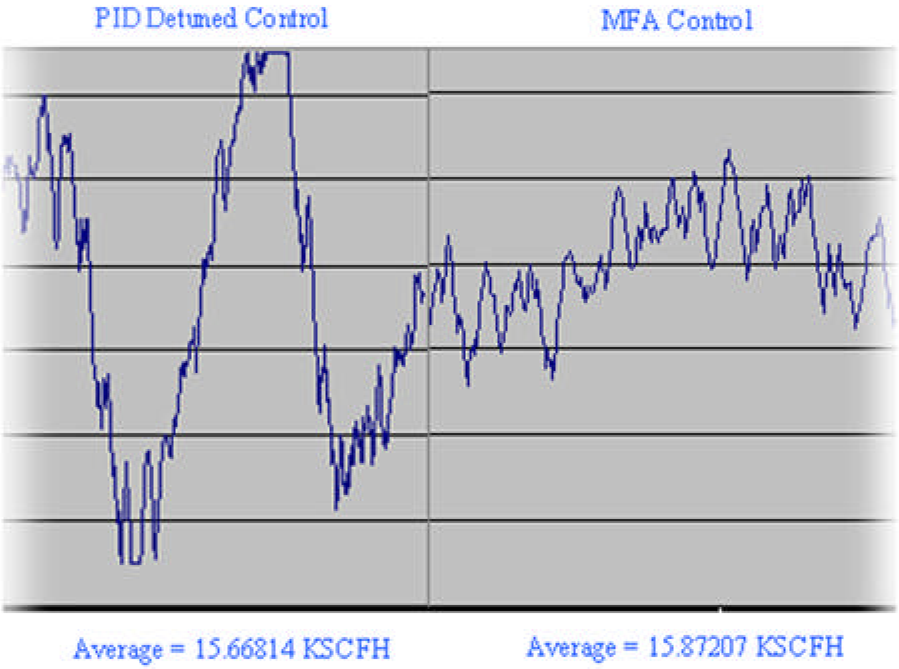


Figure 5 (below) indicates flow of high-value product. It shows a higher and more consistent gas flow with the MFA controller.

When Air Liquide engineers asked the operations staff at the McMinnville plant whether the new controller was working satisfactorily, the staff replied, "Absolutely. We are seeing fantastic results with this controller. We now think we have a better understanding of [the process]." They said the plant is setting production records and running much more smoothly, adding that plant manager Brian Keene "can't believe how good it is working."



Conclusions

The main goal of operating an ASU is to maximize product yields and maintain the operation as steady as possible. Improvements are evident in all controlled variables using model-free adaptive control technology. The return on investment is so high that the payback period can be measured in months, if not weeks.

Model-free adaptive control technology proved to be quite easy to install and commission on air separation units. Air Liquide engineers performed the entire commissioning task for the second installation at the McMinnville plant within one day. Since its installation, virtually no maintenance or re-tuning of MFA controller was required.

Using model-free adaptive control, Air Liquide achieved benefits in the areas of product yield, quality control, and perhaps most importantly, operational stability. Based on the success of these projects, Air Liquide America plans to standardize on model-free adaptive control for its advanced regulatory control applications.

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Figure 1: In a typical air separation unit (ASU), air is filtered, compressed, dried, cooled, and fed to a high-pressure cryogenic distillation column. Oxygen-rich liquid from the bottom of the high-pressure column is fed to a low-pressure column.

Figure 2: Compare PID control (left) to model-free adaptive (MFA) control (right) for the level in the high-pressure column.

Figure 3: Improved level control shown in Figure 2 (previous) is a result of improved reflux flow control shown above.

Figure 4: The switch to MFA control immediately improved purity of production from the principal column.

Figure 5: Flow of high-value product became higher and more consistent with MFA control.

To optimize production of air separation units (ASUs) in its global operations, Houston-based Air Liquide America Corp. (a unit of Air Liquide Group, Paris) constantly researches the capabilities of both new and old technologies. The company has made it a corporate goal to enable the majority of its plants to run automatically for 24 hours a day, seven days a week.

In a typical ASU (Figure 1), filtered atmospheric air is brought into the plant via the main air compressor. This air is dried and cleaned, cooled in a heat exchanger, and directed into the bottom of the high-pressure cryogenic distillation column. The bottom of the column contains oxygen-rich liquid (called rich liquid) that becomes the feed for the low-pressure cryogenic distillation column. A third cryogenic distillation column hangs off the side of the low-pressure column for processing crude argon.