ADVANCED PROCESS CONTROL FOR ULTRA-DEEP-HYDRODESULFURIZATION USING Exasmoc R3 AND Exarqe R3

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Advanced process control in the PCS (Process Control System) market is a key technology to glean the greatest profit from the existing equipment in the plant. The Advanced process control can be easily applied to in-service processes and helps stabilize and optimize operations taking process restrictions into consideration.

The Exasmoc (a multivariable model predictive control package) and Exarqe (a robust quality estimator package) released in 2000 have been in operation in many DCS (Distributed Control System) or PLC (Programmable Logic Controller) systems. Recently, Exasmoc R3 and Exarqe R3 which incorporate enhanced algorithms have been newly developed to realize operations for large-scale and critical control processes. Hence, these two packages are strongly recommended for adoption in the ultra-deep-hydrodesulfurization process which is now under consideration by world-wide oil refinery plants.

This paper introduces an example of the functions of Exasmoc R3 and Exarqe R3, which are recommended for use in high-level advanced process control.

INTRODUCTION

Yokogawa has formed an alliance with Shell Global Solutions International B.V. (SGSI) for advanced process control and has been jointly developing related products since then. As part of this collaborative work, we commercialized the Exasmoc* multivariable model predictive control package and the Exarqe* robust quality estimator package in 2000, which are used to control DCS and PLC systems based on SGSI's multivariable predictive control and quality estimation algorithms—namely, SMOC* (Shell Multivariable Optimizing Controller) and RQE* (Robust Quality Estimator).

Recently worldwide efforts have been intensifying to regulate sulfur concentration in fuel oil from an environmental viewpoint. Sulfur oxides not only produce acid rain but also significantly deteriorate the efficiency and servicing life of filtering systems which remove chemicals harmful to health from vehicular exhaust gas. Japan is obliged to provide light oil that emits sulfur oxides of 50 ppm or less, a tenth the current limit, by the end of 2004, with further plans to reduce the emission to 10 ppm or lower in the future. To meet these new standards, world-wide oil refineries including those located in Japan have been considering the use of ultra-deep-hydrodesulfurization processes. While higher-performance catalysts and processes themselves have been studied, advanced control systems that can handle ever-restricting reaction conditions have also been sought. The Exasmoc R3 and Exarqe R3 were developed in response to these market needs.

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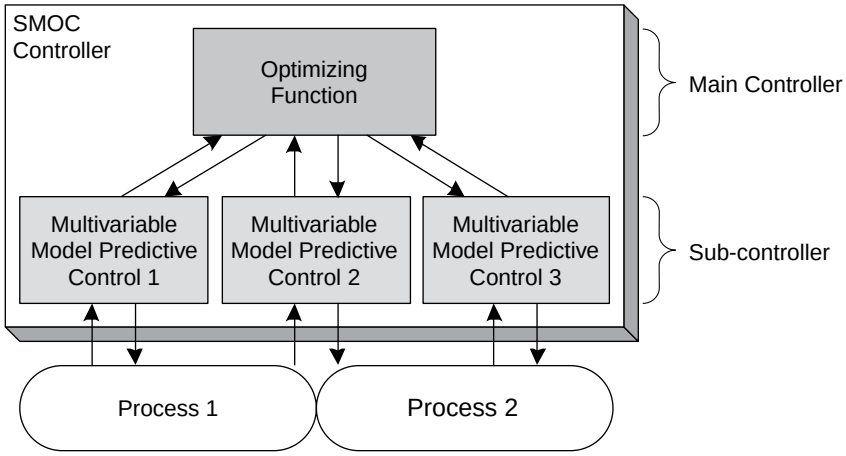

Figure 1 Two-level Structured Controller

NEW FUNCTIONS OF Exasmoc R3 AND Exarqe R3

By incorporating several new functions, Exasmoc R3 and Exarqe R3 implement advanced control of ultra-deep-hydrodesulfurization processes as well as can be used for multi-purpose, large-scale processes.

Exasmoc R3 Multivariable Model Predictive Control Package

The Exasmoc package performs on-line multivariable model predictive control, where a controller is equipped with internal dynamic behavior models of processes and gives processes optimum manipulated inputs after predicting their next step. This method is particularly effective at stabilizing or optimizing processes that are susceptible to disturbance, time delay, inverse response, and interference from other processes. The Exasmoc R3 offers the following additional functions:

- Large-scale system control
- Priority-based control
- Trend prediction

The previous versions of Exasmoc could not be used for ethylene plants or other large-scale processes that require an enormous number of inputs and outputs. The Exasmoc R3, however, has a two-level structure consisting of a main controller and sub-controllers as shown in Figure 1, which enables the overall process to be divided into groups that are comprised of control variables and manipulated variables.

Sub-controllers perform multivariable model predictive control on a group basis. The main controller determines if the current process status allows for control work by taking restrictive conditions into account and performs optimizing operations for each sub-controller. It then provides the sub-controllers with the optimum setting ranges for control variables. As the sub-controllers can operate at different control intervals with each other, the Exasmoc R3 can be adopted for a large-scale process in which fast-interval groups and slow-interval groups coexist.

A priority ranging from 1 to 100 can be specified for control variables, facilitating flexible control according to their importance. The Exasmoc R3's HMI (Human Machine Interface) displays relationships between the variables in a visually easy-to-understand tree format as shown in Figure 2.

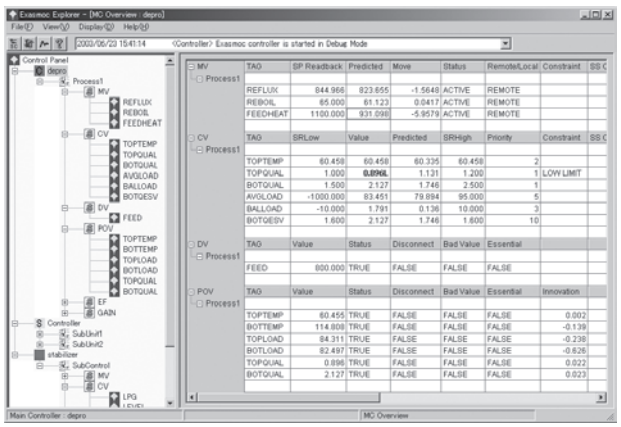

Figure 2 Exasmoc R3 Operation and Monitoring Screen

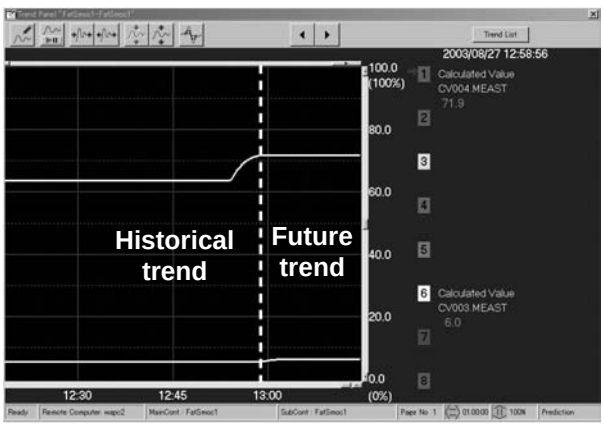

Figure 3 Predicted Trend

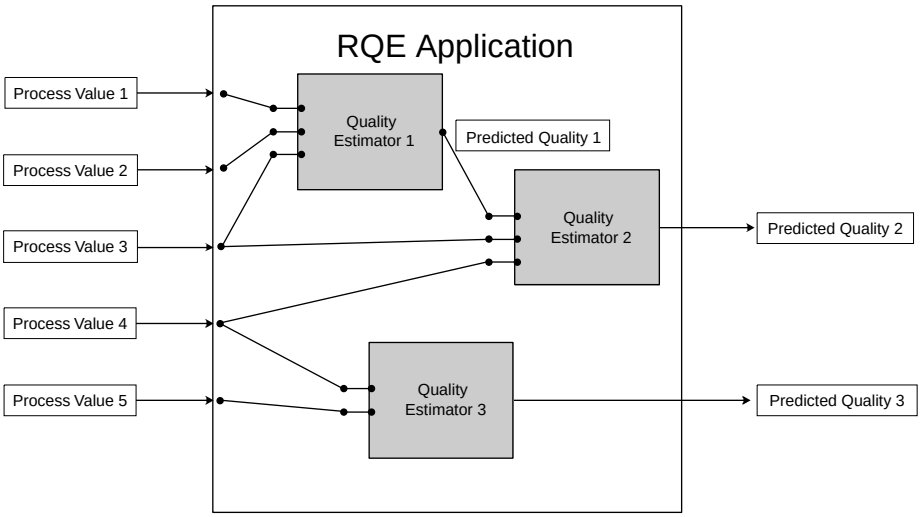

Figure 4 Multi-point Quality Estimation

The Exasmoc R3 can also display trends of predicted process variables. This function compiles predicted data and historical data which the Exasmoc outputs periodically, and then displays their changes in trend graphs. The simultaneous display of changes in both types of data neables to chronologically grasp process trends at a glance, thereby providing operators with accurate information for choosing control operations. Figure 3 shows a screen example of the trend function illustrating predicted data and historical data.

In the graph in Figure 3, a border between the predicted and historical trends is indicated by dashed lines, which represent the current time and show the past data on the left with the future data on the right. The future data as predicted data is repeatedly re-calculated by the Exasmoc R3 at regular intervals.

Exarqe R3 Robust Quality Estimator Package

The Exarqe packages perform on-line quality estimation in real time and can also be used as software sensors. Quality estimation means inferring properties or qualities that cannot be measured directly, such as freezing points and the concentration of impurities, from measurable process values that influence flow, temperature, and other properties. With other types of on-line analyses or laboratory analyses, there are time delays between the sampling and measuring of the target object, and thus reflecting the resultant estimated property values in control is difficult to optimize the system operation. On the other hand, as the Exarqe estimates property values in a consistent, real time manner, they are accurate enough to be used as the estimated current process values for controlling the system. The new Exarqe R3 also offers the following additional functions:

- Multi-point quality estimation
- Computing
- Blending

The Exarqe R3 enables estimation of multiple qualities in a quality estimator application, and a multi-stage quality estimator model, with which a predicted quality is subsequently used as an input to estimate another quality (see Figure 4), can be realized with a single application. Although building such a model previously required considering the connection timing between the relevant quality estimators, the Exarqe R3 overcame this problem by integrating the actions that are associated with a quality estimator application.

Furthermore the Exarqe R3 implements blending functions that are a practical application of the quality estimator function and that make possible estimation of integrated qualities (tank quality estimation) and tank quality control using the estimated integrated qualities. Other built-in functions are also available, including the definition capability of arbitrary operational expressions and SGSI's unique, abundant blending expressions. In combination with the Exasmoc R3, the Exarqe R3 achieves various types of blending control depending on the application. Next chapter describes an ultra-deep-hydrodesulfurization process, which is an example of advanced control attained by making the most of the aforementioned new functions.

APPLICATION OF ADVANCED CONTROL TO THE ULTRA-DEEP-HYDRODESULFURIZATION PROCESS

Combining the functions of the Exasmoc R3 and the Exarqe R3 facilitates advanced control of an ultra-deep-hydrodesulfurization process as follows.

Figure 5 shows a system configuration example where feed oils 1 to 3 with different sulfur concentrations are blended at a specified ratio; sulfur content is reduced from the mixture using hydrodesulfurization equipment; and then a properly adjusted amount of additives are added to output the final product (which is light oil in this example) within a targeted range of sulfur concentration. In this system, the Exarqe estimates the sulfur concentration of the intermediate product in real time after the hydrodesulfurization treatment, based on various data such as the pre-analyzed individual ingredients of the feed oils and the

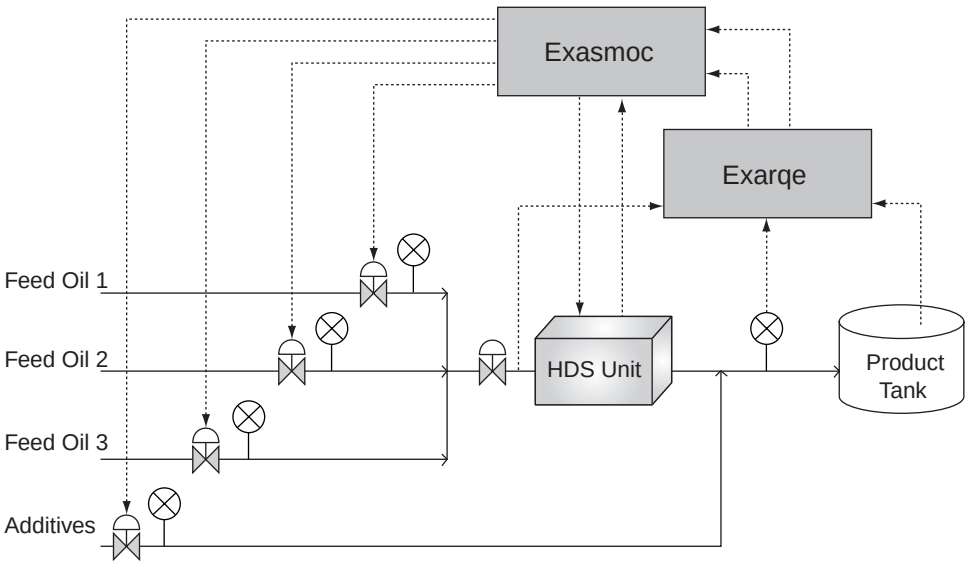

Figure 5 Advanced Control Example of Ultra-deep-hydrodesulfurization Process

additives, and process-related data including the blending ratio and temperature. The Exasmoc controls the reaction temperature and blending ratio according to actual process measurements and the estimated qualities through the Exarqe, to make sure that the final product is consistently within the targeted quality range.

As measuring sulfur concentration using conventional analyzers including gas chromatographs takes a certain amount of time, these methods are likely to generate a gap between the estimated and actual qualities due to time delays when the measurement results are reflected on the process, resulting in a final product that does not satisfy the required specifications, or that is of excessive quality caused by excessively protective system settings against possible deterioration. In general it consumes more energy to manufacture a product with excessive quality, and accordingly costs more. As a solution to these challenges, we developed a highly efficient control system that can stably output products that meet the required specifications by a narrow margin, through Exarqe R3's real-time quality estimation and Exasmoc R3's multivariable model predictive control. This control system has another advantage in that it can manufacture products with targeted quality in a continuous process and thus does not require a temporary tank that stores intermediate products halfway through the process. Overall, this system can achieve massive cost reductions by cutting an annual maintenance cost of approximately 100 million yen per tank and other costs.

CONCLUSION

The Exasmoc and the Exarqe are advanced control packages that amalgamate Yokogawa's extensive experience in the PCS field and SGSI's sophisticated technology for oil refining. It is imperative for enterprises to reduce costs by operating plants efficiently, and advanced control is expected to significantly contribute to this area. Combining the Exasmoc and the Exarqe enables process qualities to be stabilized in real time, an achievement that has never been realized with on-line or laboratory analyzers. The two packages have already been introduced to a variety of processing, such as oil and petrochemical as well as gas and ethylene, and are highly evaluated on the site.

Ultra-deep-hydrodesulfurization is known to involve many cost and technological difficulties, and its application has been widely studied in various fields. We believe that the Exasmoc R3 and the Exarqe R3 which incorporate SGSI's comprehensive practical knowledge of this technique can play an important role in yielding good results.

We will continue to upgrade the Exasmoc and the Exarqe to nurture them as the mainstays of Yokogawa's advanced control business, as well as to further increase our actual results and expertise in the relevant solutions. ◆

REFERENCE

(1) Terashima Nobuhiko, Takatsu Haruo, Okada Kenji, "'Exasmoc' Multivariable Model Predictive Optimizing Controller," Yokogawa Technical Report, Vol. 45, No. 3, 2001, pp. 35-40 (in Japanese)