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Research Article

Online Optimization Technology of Data-driven Complicated Food System

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Abstract: The study, with online optimization technology definition as the entry point, has explored online optimization procedure, relying on the analysis on its position in food enterprise comprehensive automatic food system and the overview on new data-driven control method. With the development of computer technology and the generalization of Distributed Control Food System (DCFS), the efficient computation platform and rich DCFS resource have provided a powerful hardware technology for implementing advanced process control technology like online optimization.

Keywords: Distributed control food system, online optimization technology

INTRODUCTION

In recent years, people are paying more and more attentions to energy conservation and the improvement of economic efficiency in the context of the growth of energy and raw materials costs, the change of market demands, the improvement of product quality and structure, as well as the trend of globalized environment protection (Katayama *et al*., 2005). Under such circumstances, the traditional operation with a view to steady production can no longer be able to meet the demands and has to be replaced with food enterprise automatic develop trend in which advanced technology and operational optimization of production devices are used to improve product quality and output and reduce energy consumption. Meanwhile, with the development of computer technology and the generalization of DCFS, the efficient computation platform and rich DCFS resource have provided powerful hardware technology for the implementation of advanced process control like online optimization. This method has a slow convergence and large workload in total and the final approximate optimal point tends to hard meet the original non-linear constraint. To avoid this situation, the variable change range of the linear planning question is usually limited in engineering.

MATERIALS AND METHODS

This study takes a refinery Catalytic Cracking Unit (CCU) with 1mn tons of annual processing capacity for an example. The so-called "online optimization" means the optimizer automatically and continuously gives the optimal operation conditions of decision variable, by use of the real-time measurement information during production on the basis of the change in external environment and operation objective and implement the conditions as the set value of the basic control loop or an advanced control food system to produce the maximum economic benefits (Ho and Kalman, 1966). Compared with conventional control technique, online optimization food system can achieve quick effects with small investment, making the general industrial application increase 2~5% economic benefits on the basis of the original values. Take a refinery catalytic cracking unit (CCU) with 1mn tons of annual processing capacity for an example, it can see an increase of ￥6~15 mn/year economic benefits. While taking Sinopec for example, there are over 60 large industrial CCUs and only one set of the device can achieve over ￥360 mn benefits. Furthermore, online optimization food system can also be used for atmosphere-vacuum distillation and some other production devices in process industries like refining and petrochemical industry.

The position of online optimization in food enterprise comprehensive automatic food system: We can find while studying a comprehensive automatic food system in a factory or an food enterprise that it is almost possible to realize an integration of modeling, control, optimization and management over such a complicated and diversified food system with a single and uniform algorithm. The separation of functions from levels is a practical method, which specially means roughly dividing food enterprise comprehensive automatic food system into several levels lengthways based on industrial production management, operation conditions, the frequency of decisions and the size of vision. The hierarchical structure typical of food enterprise comprehensive automatic food system can be seen in Fig. 1, in which the down most control level concretely includes different control schemes like basic

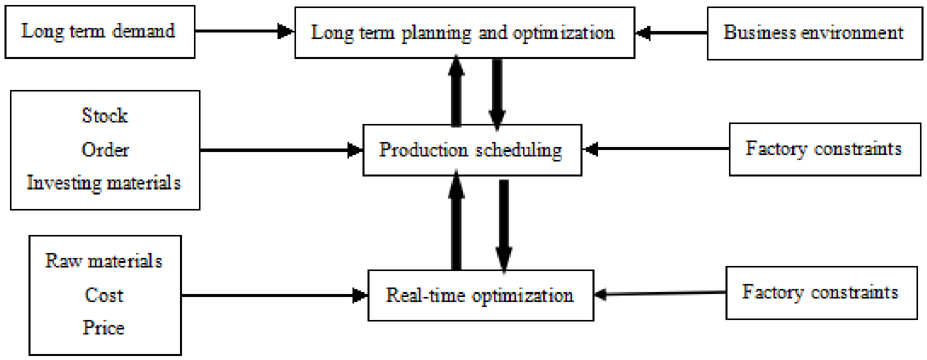

Fig. 1: The hierarchical structure typical of food enterprise comprehensive automatic food system

loop control, advanced control. The basic loop control constitutes the footstone of the whole automatic production process, mainly functioning by using PID-based convention control to get some process parameters stabilized around the set values to realize safe production and steady operation. The major function of advanced control is to provide a better control effect than basic loop, able to suit the conditions of the complicated dynamic property, time delay, multivariable, immeasurable and unconstrained variables and achieve an excellent control performance as the operation conditions change. An advanced control can fully realize the potential of the device and make production operation more reliable and convenient. The control strategy based on model is the major technical means of the advanced control, typically represented by the well-known model prediction control. The major function of the constrained control is to adjust or delete in time the optimization result not meeting equipment constraint conditions and conduct boundary condition conversion with the change of food system operation status to acquire the optimal operation condition.

The issue of optimization exists at all the levels of control, optimization, scheduling and planning decision and can achieve different economic benefits. The optimal control produces economic benefits by improving the dynamic control precision of the controlled variables and the maximum production efficiency while guarantying quality; the operation conditions for online operation optimization is the best and makes sure production always in the optimal situation to gain economic returns; the optimal scheduling relies on reasonable allocation and scheduling of the raw materials, intermediate products, energy in a large enterprise and properly deals with the failures in certain links of continuous industrial process, to keep balance of production and seek the maximum economic benefits; however, the long-term planning decision pursues the maximum economic profits by organizing production at the greatest efficiency in light of market situation and order contracts, reduce cash flow and inventory and realize the optimal production scheduling.

RESULTS AND DISCUSSION

New data drive control method: Data drive control is originated from computer science and only in recent years, the definition of control field has arisen. AlGhazzawi and Lennox (2009) gave a definition to data drive control "controller design does not include mathematic model information in controlled process, but designs controller only by using the online and offline I/O data of the controlled food system and the knowledge acquired from data process; and under certain hypothesis, it is also a control theory and method with convergent and stable guarantee and robust conclusion". In his study, he also explained the background and applicable conditions of the data drive control and classified data drive method based on its online and offline characteristics, or the characteristics of the off and on-line data combination.

Online optimization implementation process:

Linear subspace recognition: Time-varying characteristic widely exists in practical industrial production. Therefore, it requires using current sampling data online recognition food system model to realize control and decision-making over the current dynamic characteristics of the food system, as shown Fig. 2. Meanwhile, online adjusted food system model is also needed for the methods like self-adaption control and self-adaption prediction.

Saturated constraint optimization control: Saturated constraint optimization control is also a common characteristic in practical food system, such as flow-limiting valve, liquid level, bearing capacity of mechanics and sensor range, etc. Predictive control is generally recognized as the sole advanced technology that can deal with online optimization control of the

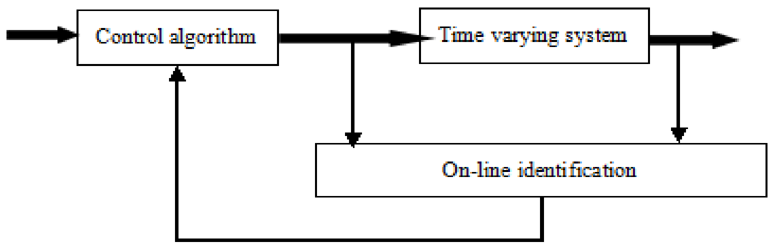

Fig. 2: Online recognition and control framework

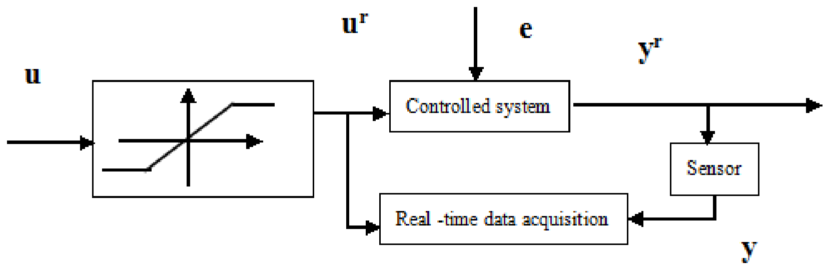

Fig. 3: Saturated constrained food system framework

multivariable constrained food system relying on food system advantages in visualized approach (van Helvoort *et al*., 2008) and thus has been widely and successfully used in complicated industrial production (Xi and Kung, 1993). The control volume acquired from constrained optimization control and the output data from sensor sampling can realize online recognition and control of the saturated constraint controlled food system, as shown in Fig. 3.

Steady state detection: Among the current steady state detection methods, the most common is to make linear regression for the data collected within a period of time and conduct T test for the regression results. The slope acquired from the regression can reflect the change tendency of the data. When the slope has a sharp deviation from 0, the food system can almost never operate at a steady state. The trouble of the online algorithm lies in fixing an appropriate time length and requiring save plenty of data, which is an apparent overload for DCFS food system widely applied in industrial production and unfavorable to realize online judgment.

Successive linear programming, SLP:
Successive linear programming, SLP: The basic thought for this method is to expand the constraints and target function to be a linear Taylor's series at certain approximate solution, use a linear planning question to approximately replace a non-linear planning question and rely on the common linear planning program to seek the solution. That is applicable in such a situation as linear planning far outnumbers the non-linear planning in the constrained condition.

CONCLUSION

The wide application of the advanced control technology represented by multivariable production control has greatly enhanced the stability and security industrial production and also further paved the road for the rising and application of online optimization technology.

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