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DEVELOPING ADVANCED PROCESS CONTROL SYSTEM FOR MANUFACTURING PROCESSES USING VIRTUAL ANALYZER

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Abstract. *This research reflects outlines the main potential features of Advanced Process Control (APC) systems for improved control of technological processes and production. It is shown developing APC systems using a virtualized analyzer (VA) is a very effective technique to increase the efficiency of industrial production. This research reflects the main steps of generating VA as part of the APC system and also describes the key features of each step-in terms of analyzer synthesis.*
Keywords: *advanced control systems, virtual analyzers, modeling and optimization of technological processes, industrial automation.*

Аннотация. *Мақолада технологик жараёнлар ва ишлаб чиқаришдаги бошқариш тизимини янада кучайтириш учун қўлланилиши кўзда тутилган "Advanced Process Control (APC)" (Жараёнларни Такомиллашаган Бошқариш) тизимининг энг муҳим ва потенциал хусусиятлари кўрсатиб чиқилган. Саноат ишлаб чиқаришларининг унумдорлигини ошириш учун виртуал анализаторлар ёрдамида "Advanced Process Control" тизимларини ишлаб чиқиш энг самарали усуллардан эканлиги кўрсатиб ўтилган. Қўшимча равишда "Advanced Process Control" тизимининг маълум бир қисми сифатида қўлланилган виртуал анализаторларни яратишнинг асосий босқичлари ҳам кўриб чиқилган. Бундан ташқари, таҳлил қилиш ва синтезлаш жараёнларидан келиб чиққан ҳолда виртуал анализаторларни яратишнинг ҳар бир босқичларининг асосий хусусиятларига тавсиф бериб ўтилган.*
Таянч сўзлар: *такомиллашган бошқариш тизимлари, виртуал анализаторлар, технологик жараёнларни моделлаштириш ва оптималлаштириш, саноатни автоматлаштириш.*

Аннотация. *В работе отражены возможности APC-систем (Advanced Process Control) усовершенствованного управления технологическими процессами и производствами. Показано, что создание APC-систем с использованным виртуального анализатора (ВА) является действенным инструментом повышения эффективности промышленного производства. Отражены этапы создания ВА в составе APC-системы и раскрыты ключевые особенности каждого этапа синтеза анализатора.*
Ключевые слова: *системы усовершенствованного (продвинутого) управления, виртуальные анализаторы, моделирование и оптимизация технологических процессов, индустриальная автоматизация.*

Introduction

Nowadays the oil-fat industry is one of the leading industries in terms of the importance of the products it produces, which determines the food security of countries. Vegetable oil production with guaranteed high-quality leads to improving its competitiveness in the market, and, also, provides the desired consumer properties of the final product.

One of the main stages in the vegetable oil refining process is the neutralization operation, which is carried out to remove free fatty acids from the vegetable oil composition. The main technological parameters that determine the effectiveness of the neutralization process are the concentration and the amount of the neutralizing agent. These parameters can be assessed by the content of free fatty acids in vegetable oils and are sent to the neutralization process [1].

It is impossible to obtain refined deodorized (high quality) vegetable oil without advancing the current control system of complex heat and mass transfer processes, which should deal with the identification of poor-quality products, and, also, prevents its occurrence. Advanced Process Control

(APC) systems can provide productive implementation methods and tools for the systematic assessment using Virtual Analyzer (VA) of vegetable oil quality at the refining stage.

Modeling, Optimization and Advanced Control of Technological Processes and Production.

Distributed control systems (DCS) of vast manufacturers, Honeywell, GE Intelligent Platforms, Siemens, Emerson Process Management, Yokogawa, and others are widely implemented at the enterprises of the oil and fat industry. At the same time, despite a fairly high level of automation of sites, redevelopments, the level of shop automation often leaves much to be desired [2]. Considering the huge number of interconnected technologies used at the enterprises of the oil and fat industry, and also, the increased safety requirements that have developed for decades, today it is extremely important to improve the efficiency of both individual installations and a whole complex of equipment using non-technological methods, which means without changing technology. This can be achieved through an integrated approach - economic, organizational, and, mainly, IT solutions based on modern information technology.

Fats and oils industry enterprises need solutions that allow not only to collect data on the implementation of the production program and analyze the efficiency of production facilities, but also to solve a variety of tasks - from the stabilization of a technological facility to its optimization according to a given criterion (maximum productivity, minimum cost, minimum specific energy consumption, and so on). To extract all possible benefits from the control system of technological and production facilities, to identify and maintain optimal operating modes of installations by improving the control system, today the means of automated control systems for advanced process control allow [3].

Today with the help of APC System techniques it is possible to extract all plausible benefits from the control system of technological and production facilities, as well as, to identify and maintain optimal operating modes of installations by improving the control system. The basis of the APC system consists of process models that can be used to create virtual analyzers, to solve problems of multiparametric control, stabilization and optimization of technological modes based upon key performance indicators. Due to this, the main tasks of APC systems can be categorized in the following way:

- increasing productivity and profitability;
- cost reduction;
- minimization of the influence of the "human factor".

Comparison of the traditional control system and the APC-system shows that the means of the latter turn out to be a more effective tool for automatic control (Fig. 1).

A comparison of the traditional control system and the APC system shows that the usage of the latter turns out to be a more effective tool for automatic control (Fig. 1).

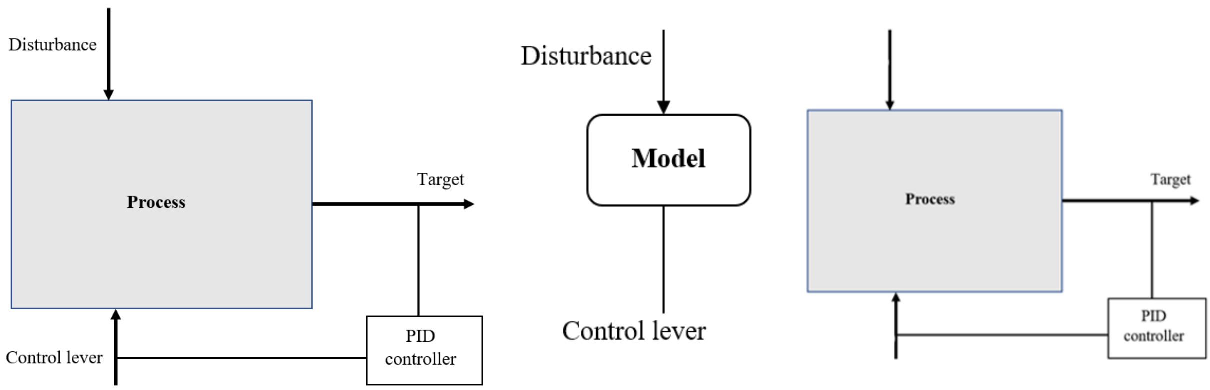

Fig. 1. ***Impact on disturbance in the traditional control system and the ARS-system.***

With a traditional control system, the influence of a disturbance on the control target is recorded only sometime after the disturbance appears. The response coefficient and transmission time depend on the dynamics of the technological process. The deviation of the target variable from the required set value enters the input of the PID controller, which, by changing the controlled variable (control lever), eventually returns the target variable to the set value and compensates for the disturbance affecting the technological process.

In the case of using an APC system, the controller registers changes in disturbances, and the built-in process model immediately begins to calculate the value of the control action necessary to compensate for the disturbance. Thus, the impact on the control lever is carried out even before the target variable deviates from the set value under the influence of a disturbance. Due to this, the APC system approach ensures the stability of the production process and improvement of the quality of production management [6,7].

Advanced control system using a virtual analyzer is a subject to the improvement of production efficiency

Currently, manufacturers most often employ flow analyzers (FA) for measurements, which are used to determine the physical and chemical properties of products in real-time and various laboratory analysis tools. Both have their advantages and disadvantages. Thus, even though they have good accuracy, laboratory analyses are carried out periodically, which does not allow for rapid response to changes in the current technological process (for example, to change the operating modes of the installation). Despite the high accuracy and continuity of measurements, self-diagnosis, and visualization of readings, flow analyzers have their drawbacks: the need for periodic calibration of readings, the requirements of qualified maintenance, and, most importantly, the high cost of equipment. The use of virtual analyzers (VA) in the enterprise serves as an addition to the methods described above. At the same time, the VA is a model designed for indirect measurement of qualitative indicators of a particular process, built based on archival production data and laboratory analysis data performed by ASTM international. The selection of regressors for building a model of the corresponding process is determined by the technologist, that is, the knowledge of specialists and the experience they have accumulated during the operation of a particular installation.

Thus, VA allows the operator at a certain stage to monitor the progress of the process in the event of a failure of FA or a delay in laboratory analysis data, especially in cases where there is no Laboratory Information Management System at the plant.

Today, mathematical models of virtual analyzers or virtual analyzers in the form of regression equations are used in practice. On the one hand, it takes a certain amount of time, on the other – the constructed model at the time of its receipt may not correspond to the technological process existing at the enterprise at the moment. The calculation of the model begins with the analysis of the collected statistical information and the choice of a regression method and ends with the resulting functions. The resulting model corresponds only to the specific operating conditions of the installation, therefore, with any significant change in the characteristics of the simulated object (for example, after major repairs), an adjustment of the model used is required, and the entire laborious process of calculating it begins from the beginning.

As a rule, virtual analyzers are part of the tools of the APC system implemented at the enterprise. This makes it possible to analyze the technological process in a short time in a semi-automatic mode, identify causal but investigative links, as well as find opportunities for improvement and implement them in the "operator's adviser" mode or settings directly transmitted to regulators. Further correction of the mathematical model in online or offline modes is carried out both according to the quality indicators of the model itself (the coefficient of determination R2 is most often used) and according to FA and laboratory analyses. It should be noted that an important feature of creating a full-scale APC system complex is to perform each subsequent step only after preliminary analysis of statistical data and comparison of the results with the existing management system. The analysis can be performed using the Proficy CSense software product of GE Intelligent Platforms. A positive result of the analysis, allowing to start the implementation of the next stage, is considered to be the identified resource (opportunity) to improve the efficiency of the management system. The following key features can be identified for the implementation of the VA for each of the stages:

1. Data preparation includes a detailed study of the algorithms of the installation, primarily with technologists, specialists who know the control object not only from the perspective of regulations but also at the level of intuition. The matrix of cause-and-effect relationships identifies the process targets and also distributes the influencing parameters into the following groups: regulated, observed, and perturbations. Statistical data were downloaded from the archive of the Manufacturing Execution System in tabular form in *.csv format [4].

2. For calculations and visualization of statistical information, the Proficy Troubleshooter tool, which is part of the Proficy CSense package, can be used. This tool not only allows to present information graphically (histograms, graphs), build a correlation matrix, and exclude collinear inputs (a high degree of correlation in the matrix is highlighted in pink and purple, and excluded parameters are gray), but also makes several iterations to exclude data from the model that does not agree with the usage of the technological process. At this stage, in the first approximation, it is possible to assess the prospects for process optimization as the difference between the average statistical value of the target process indicator and the optimal value, which subsequently forms the basis of the feasibility study of the project [5-8].

3. The model is built completely automatically, with two-thirds of the samples, as a rule, used to build patterns and one-third - for verification. Since the division of samples in the program occurs randomly to make sure that the R2 of the model does not change by more than 1-2% (the model is considered good enough when this indicator is greater than or equal to 85-90%), the model is built several times.

4. The stage of extracting new knowledge is a step towards optimizing the process and at the same time a tool for an experienced technologist that allows checking the adequacy of the model according to the "What if?" principle in a very simple way: by pulling the slider of the influencing parameter in one direction or another directly on the screen, it can be seen how the model predicts a change in the target indicator. Next to it, an analysis of the influencing factors from the number of input variables is graphically presented, considering the weighting coefficients, their influence on a particular part of the process, as well as the rules of fuzzy logic formed by the system at the modeling stage.

5. Assessment of possibilities is also an automatic process where, based on the model, our preliminary assessment of improvements made at the stage of processing static information is checked. Here it is important to set regulatory restrictions for regulated parameters.

6. The action model is built using the Architect tool, also included in the Proficy CSense package. A set of built-in blocks allows, in the simplest case, to receive data from a real-time source (a controller, an automated process control system server, a relational database, or a production data warehouse, for example, Proficy Historian), using a model to develop a predictive value of the target parameter and transmit the information received to the operator. At the stage of constructing the action model, the task of optimizing the process is also carried out.

Thus, by setting the limits of the regulated parameters according to the regulations and the optimization function, for example, maintaining the maximum concentration of the product name of what the virtual analyzer bears, they receive information about what the target indicator could be, and how much needs to be corrected.

All recommendations can be issued either in the "operator's adviser" mode or at the level of the controller as setpoints to regulators.

The exchange of information with the Proficy CSense package can be organized using the Open Platform Communications protocol. The architecture of interaction between the APC system and the traditional automated control system is shown in Fig. 2.

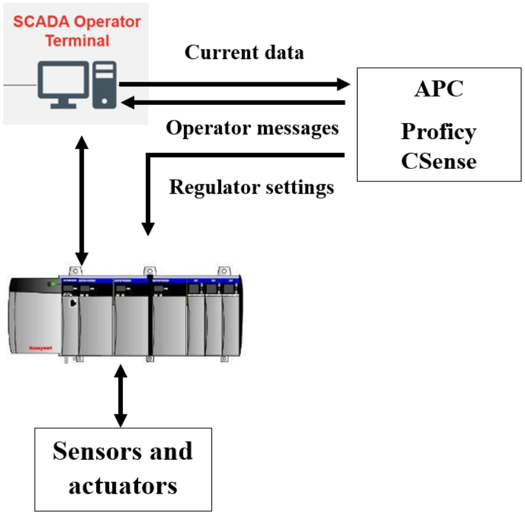

Fig. 2. ***The architecture of interaction between the APC system and the traditional automated control system.***

At present, to ensure further compliance of the model with the real technological process, it is necessary to adjust its knowledge base on time. The need to adapt the model may be caused by changes in the characteristics of the main equipment (failure of sensors, clogging of chimneys, etc.), changes in environmental conditions, or the results of internal diagnostics of the model by Proficy CSense, which are an indicator of the competence of using the model in the installation management [8-13].

Conclusion

1. Experience shows that even a small set of information may be enough to prepare an adequate model and optimize the management of the technological process in the enterprise. The result of this improvement is measurable. The difference between the average values of the target before using the virtual analyzer with the optimization function and after building the APC system can be from one to tenths of a percent, which can produce thousands of tons of product per year.

2. The archive of the control system contains a model of the process for different seasons, different conditions of the equipment. This data can be retrieved as a link to a data source or as a text file.

3. Above mentioned investigation shows that even a small set of information may be enough to prepare an adequate model and optimize the technological process management in the manufacturing company. The result of this improvement is quite measurable. The difference between the average values of the target indicator before using a virtual analyzer with an optimization function and after building an APC system can range from units to tenths of a percent, which can produce thousands of tons of product per year.

4. An important component of the modeling process at all its stages is the accumulation, mutual adjustment of statistical conclusions with the experience and knowledge of technologists, which ultimately allows talking about the APC system as an expert management system.

5. Analyzing the efficiency of the technological process and finding ways to optimize does not require serious programming experience or deep knowledge of mathematical apparatus (artificial neural networks, fuzzy logic, etc.) from the specialist solving this problem – this is taken over by the Proficy CSense software package from GE Intelligent Platforms.

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