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INTELLIGENT SYSTEM FOR THE PRODUCT COMPOSITION MEASUREMENT AND CONTROL

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Abstract- This paper presents PLC and SCADA based structural and software models to achieve higher accuracy in the production process with the self-monitoring and correction capabilities, improved system characteristics, integrated usage of various methods and tools for the operative monitoring and measurement-control, infrared and far-infrared-range measurement result processing, product characterization in terms of determination of qualitative and quantitative composition indicators using optical analysis methods together with external and internal factors affecting the quality such as temperature and composition variation, the measurement and monitoring of color index parameters to evaluate the quality of the product. The structural and functional models of the measurement-control system for product composition and its physical imitation algorithm are introduced.

Keywords: Liquid Crystal Filter, Intelligent System, Colorimeter, Spectroscopy, Functional Model, Physical Model, PLC, Complex Method.

1. INTRODUCTION

The processing sector of fuel and energy complexes is characterized by the acquisition of finished products and semi-finished products for use and sale, and the development of new methods and tools for control and monitoring of each technical and technological process affecting product quality, decision-making processes based on new information still remain to be relevant today. In this case, taking into account the main features of the process, it is planned to use cost-effective methods and tools that have been applied on an industrial scale [1-3].

Increasing the effectiveness of the results should be accompanied by an improvement in the quality of the product, which is not possible without taking into account the nature of the processes taking place in the research object. The selection of methods and tools by these characteristics, the correct assessment of the internal parameters characterizing the process, and the parameters under the internal and external factors is a key issue in ensuring quality indicators [4].

The research raises the issue of measurement and control through the use of intelligent systems based on measurements, evaluation, comparative analysis, and, as a result, automatic decision-making, and control, to improve product quality [5, 6].

Several sources have suggested the possibility of obtaining higher accuracy using the Saybolt color scale when estimating the color of oil and oil products following the Saybolt and ASTM standards [7, 8]. However, the limitations of color shades and the determination of color based on only three colors have a negative impact on the increase in evaluation error and the correct assessment of quality. Also, when assessing the quality of a product, based on one quality indicator does not allow to achieve the required quality as a result [9-11].

Thus, only the color indicator may not be an indicator of the production of the product in accordance with the required quality. In this regard, the difference in composition, temperature, etc. Operational control of product quality is an urgent issue by studying other external and internal factors affecting the quality and taking into account the results of the analysis in the measurement and control process.

2. MATERIAL AND METHOD

2.1. Presentation of the Main Material

Unlike contact measurement methods, which are used to assess the condition of an object (in this case, a product), diagnostics based on non-contact measurement methods and tools are of particular importance, and the application of such studies in different ranges of electromagnetic waves is wide and varied.

In this type of study based on remote measurements, the output information function depends on the input parameters conditioned by the number of these ranges:

$$F_s = f\left(x_1, x_2, x_3, ..., x_n\right) \text{ , } n = 12 \div 240 \qquad (1)$$

where, x_1, ..., x_n are subtypes the corresponding measurement results, and n is the number of sub-ranges from which these results are obtained or the number of appropriate channels. In this case, the number of measurement results $N_m = n$.

Over a wide range of studies at small wavelengths, a large amount of data is obtained in accordance with the characteristic parameters that reflect the current state of the object. This reduces the intensity of research results and decision-making efficiency. Research conducted in the course of direct technological processes is of special importance, and at the same time, the requirements become more stringent. In solving the problem, the selection of innovative methods and tools based on new techniques and technologies, the creation of a modified system for controlling the composition of the product, which allows determining the quality of the research object used on their basis, becomes urgent.

Note that during measurements made in accordance with the primary colors [10],

$$F_s = f\left(x_R, x_G, x_B\right),\ n=3 \text{ and } N_m = 3 \tag{2}$$

The efficiency increases due to the reduction in the number of channels, but it is advisable to take measurements in smaller sub-ranges to increase the measurement accuracy. In this case,

$$F_s = f\left(x_R, x_G, x_B, x_{RY}, x_{GO}, x_{BM}\right),\ n=3 \text{ and } N_m = 6$$

or (3)

$$F_s = f\left(x_{Rkj}, x_{Gkj}, x_{Bkj}\right),\ n=3,\ j=1\div 3 \text{ and } N_{mn}\times j$$

where, one, two, or three sub-bands on the same channel, resulting in three, six, and nine channels, if required.

Of particular importance in the organization of measurements by the proposed method is the selection of the channel control frequency and the fact that the selected sub-bands are informative sub-bands. As a result of operative analysis of the results of the first measurements, it is determined to which channel the next sub-ranges are carried out. That is, measurements are made not based on rigid logic, but based on intelligent logic, adaptive hardware software, which reduces the likelihood of obtaining additional information and increases the accuracy of measurements.

During the study, simultaneous measurements were made at the measurement nodes located at different stages of the technological process, taking into account the nature of the poses, it is possible to compare the results obtained in time with the results to be obtained by the technological procedure and training. It should be noted that the violation of the technological process for one reason or another, changing the composition of the organizers, etc. Preliminary assumptions such as making the use of complex measurements more important in the product quality control process. Thus, at a certain stage, when the quality control of the product is carried out by various parameters, if the results obtained confirm other results, the degree of conformity of the results to the quality of the product increases, and errors and mistakes decrease. It is advisable to control the temperature and density along with the color indicators, comparing with the data of the technical parameters of the appropriate stage of the correct process placed in the database by measuring the parameters important during the technological process to control product quality.

It is recommended to use liquid crystal-based filters controlled by the release band. The setting of the filters is controlled by the PLC controller, which is used in the system and transmits signals of the appropriate frequency from the power supply. The total signal at different stages of the production process of the measurement system, without taking into account external influences, can be presented in the following three main colors:

$$\begin{aligned} U_c = {} & \int_{\lambda 1}^{\lambda 2}\left[E(\lambda)x(\lambda)d\lambda\right] + \int_{\lambda 3}^{\lambda 4}\left[E(\lambda)y(\lambda)d\lambda\right] + \\ & + \int_{\lambda 5}^{\lambda 6}\left[E(\lambda)z(\lambda)d\lambda\right] \end{aligned} \tag{4}$$

where U_c is a radiation signal received by a typical RGB system; $x(\lambda), y(\lambda), z(\lambda)$ - to work « tricolor » function. $\lambda_1 \div \lambda_6$ correspondingly *B*, *C*, *G*, *Y*, *M*, *R* are wavelengths corresponding to their colors 1) If the expression is expressed in two consecutive stages of the production process measured by the RGB system, it is obtained as follows:

$$\begin{aligned} U_{CM1} = {} & \int_{\lambda 1}^{\lambda 2}\left[E_{M1}(r_l)r(l)dr_l\right] + \\ & + \int_{\lambda 3}^{\lambda 4}\left[E_{M1}(g_l)g(l)dg_l\right] + \\ & + \int_{\lambda 5}^{\lambda 6}\left[E_{M1}(b_\lambda)b(\lambda)db_\lambda\right] + \\ & + \int_{\lambda 7}^{\lambda 8}\left[E_{M1}(c_\lambda)c(\lambda)dc_\lambda\right] + \\ & + \int_{\lambda 9}^{\lambda 10}\left[E_{M1}(y_\lambda)y(\lambda)dy_\lambda\right] + \\ & + \int_{\lambda 11}^{\lambda 12}\left[E_{M1}(m_\lambda)m(\lambda)dm_\lambda\right] \end{aligned} \tag{5}$$

$$\begin{aligned} U_{CM2} = {} & \int_{\lambda 1}^{\lambda 2}\left[E_{M2}(r_\lambda)r(\lambda)dr_\lambda\right] + \\ & + \int_{\lambda 3}^{\lambda 4}\left[E_{M2}(g_\lambda)g(\lambda)dg_\lambda\right] + \\ & + \int_{\lambda 5}^{\lambda 6}\left[E_{M2}(b_\lambda)b(\lambda)db_\lambda\right] + \\ & + \int_{\lambda 7}^{\lambda 8}\left[E_{M2}(c_\lambda)c(\lambda)dc_\lambda\right] + \\ & + \int_{\lambda 9}^{\lambda 10}\left[E_{M2}(y_\lambda)y(\lambda)dy_\lambda\right] + \\ & + \int_{\lambda 11}^{\lambda 12}\left[E_{M2}(m_\lambda)m(\lambda)dm_\lambda\right] \end{aligned} \tag{6}$$

$$\begin{aligned} U_{CMn} = {} & \int_{\lambda 1}^{\lambda 2}\left[E_{Mn}(r_\lambda)r(\lambda)dr_\lambda\right] + \\ & + \int_{\lambda 3}^{\lambda 4}\left[E_{Mn}(g_l)g(l)dg_l\right] + \\ & + \int_{\lambda 5}^{\lambda 6}\left[E_{Mn}(b_\lambda)b(\lambda)db_\lambda\right] + \\ & + \int_{\lambda 7}^{\lambda 8}\left[E_{Mn}(c_\lambda)c(\lambda)dc_\lambda\right] + \\ & + \int_{\lambda 9}^{\lambda 10}\left[E_{Mn}(y_\lambda)y(\lambda)dy_\lambda\right] + \\ & + \int_{\lambda 11}^{\lambda 12}\left[E_{Mn}(m_\lambda)m(\lambda)dm_\lambda\right] \end{aligned} \tag{7}$$

and

$$\begin{aligned}
U_{CMS} &= \int_{\lambda 1}^{\lambda 2}\left[E_{MS}\left(r_\lambda\right) r(\lambda)\, dr_\lambda\right]+ \\
&+\int_{\lambda 3}^{\lambda 4}\left[E_{MS}\left(g_\lambda\right) g(\lambda)\, dg_\lambda\right]+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{MS}\left(b_\lambda\right) b(\lambda)\, db_\lambda\right]+ \\
&+\int_{\lambda 7}^{\lambda 8}\left[E_{MS}\left(c_\lambda\right) c(\lambda)\, dc_\lambda\right]+ \\
&+\int_{\lambda 9}^{\lambda 10}\left[E_{MS}\left(y_\lambda\right) y(\lambda)\, dy_\lambda\right]+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{MS}\left(m_\lambda\right) m(\lambda)\, dm_\lambda\right]
\end{aligned} \tag{8}$$

where, $E_{M1}(\lambda)$ is the intensity of the input signal corresponding to the first measuring point of the system; $E_{M2}(\lambda)$ is the intensity of the input signal corresponding to the second measurement point, U_{CMn} is the intensity of the input signal corresponding to the n measurement point, U_{CMS} is the intensity of the input signal corresponding to an exemplary measurement point.

For the first measurement point according to the color distortion at these two points, depending on various internal and external factors $\Delta R_1,\ \Delta G_1,\ \Delta B_1$, or $\Delta R_1,\ \Delta G_1,\ \Delta B_1,\ \Delta C_1,\ \Delta Y_1,\ \Delta M_1$ for the second measurement point $\Delta R_2,\ \Delta G_2,\ \Delta B_2$ or $\Delta R_1,\ \Delta G_1,\ \Delta B_1,\ \Delta C_1,\ \Delta Y1_1,\ \Delta M_1$ and for the n measurement point $\Delta R_n,\ \Delta G_n,\ \Delta B_n$ or $\Delta R_n,\ \Delta G_n,\ \Delta B_n,\ \Delta C_n,\ \Delta Y_n,\ \Delta M_n$.

If we mark it as, we get the following expressions according to the total signals at those points for six channels in accordance with:

$$\begin{aligned}
U_{CM1} &= \int_{\lambda 1}^{\lambda 2}\left[E_{M1}\left(r_\lambda\right) r(\lambda)\, dr_\lambda-\Delta R_1\right] k_{1R}+ \\
&+\int_{\lambda 3}^{\lambda 4}\left[E_{M1}\left(g_\lambda\right) g(\lambda)\, dg_\lambda-\Delta G_1\right] k_{1G}+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{M1}\left(b_\lambda\right) b(\lambda)\, db_\lambda-\Delta B_1\right] k_{1B}+ \\
&+\int_{\lambda 7}^{\lambda 8}\left[E_{M1}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_1\right] k_{1C}+ \\
&+\int_{\lambda 9}^{\lambda 10}\left[E_{M1}\left(y_\lambda\right) y(\lambda)\, dy_\lambda-\Delta Y_1\right] k_{1Y}+ \\
&+\int_{\lambda 11}^{\lambda 12}\left[E_{M1}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_1\right] k_{1M}
\end{aligned} \tag{9}$$

$$\begin{aligned}
U_{CM2} &= \int_{\lambda 1}^{\lambda 2}\left[E_{M2}\left(r_\lambda\right) r(\lambda)\, dr_\lambda-\Delta R_2\right] k_{2R}+ \\
&+\int_{\lambda 3}^{\lambda 4}\left[E_{M2}\left(g_\lambda\right) g(\lambda)\, dg_\lambda-\Delta G_2\right] k_{2G}+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{M2}\left(b_\lambda\right) b(\lambda)\, db_\lambda-\Delta B_2\right] k_{2B}+ \\
&+\int_{\lambda 7}^{\lambda 8}\left[E_{M2}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_2\right] k_{2C}+ \\
&+\int_{\lambda 9}^{\lambda 10}\left[E_{M2}\left(y_\lambda\right) y(\lambda)\, dy_\lambda-\Delta Y_2\right] k_{2Y}+ \\
&+\int_{\lambda 11}^{\lambda 12}\left[E_{M2}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_2\right] k_{2M}
\end{aligned} \tag{10}$$

$$\begin{aligned}
U_{CMn} &= \int_{\lambda 1}^{\lambda 2}\left[E_{Mn}\left(r_\lambda\right) r(\lambda)\, dr_\lambda-\Delta R_n\right] k_{nR}+ \\
&+\int_{\lambda 3}^{\lambda 4}\left[E_{Mn}\left(g_\lambda\right) g(\lambda)\, dg_\lambda-\Delta G_n\right] k_{nG}+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{Mn}\left(b_\lambda\right) b(\lambda)\, db_\lambda-\Delta B_n\right] k_{nB}+ \\
&+\int_{\lambda 7}^{\lambda 8}\left[E_{Mn}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_n\right] k_{nC}+ \\
&+\int_{\lambda 9}^{\lambda 10}\left[E_{Mn}\left(y_\lambda\right) y(\lambda)\, dy_\lambda-\Delta Y_n\right] k_{nY}+ \\
&+\int_{\lambda 11}^{\lambda 12}\left[E_{Mn}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_n\right] k_{nM}
\end{aligned} \tag{11}$$

and

$$\begin{aligned}
U_{CMS} &= \int_{\lambda 1}^{\lambda 2}\left[E_{MS}\left(r_\lambda\right) r(\lambda)\, dr_\lambda-\Delta R_S\right] k_{sR}+ \\
&+\int_{\lambda 3}^{\lambda 4}\left[E_{MS}\left(g_\lambda\right) g(\lambda)\, dg_\lambda-\Delta G_S\right] k_{SG}+ \\
&+\int_{\lambda 5}^{\lambda 6}\left[E_{MS}\left(b_\lambda\right) b(\lambda)\, db_\lambda-\Delta B_S\right] k_{SB}+ \\
&+\int_{\lambda 7}^{\lambda 8}\left[E_{MS}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_S\right] k_{SC}+ \\
&+\int_{\lambda 9}^{\lambda 10}\left[E_{MS}\left(y_\lambda\right) y(\lambda)\, dy_\lambda-\Delta Y_S\right] k_{SY}+ \\
&+\int_{\lambda 11}^{\lambda 12}\left[E_{MS}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_S\right] k_{SM}
\end{aligned} \tag{12}$$

where, k_{1R}; k_{1G}; k_{1B}; k_{1c}; k_{1Y}; k_{1M}; k_{2R}; k_{2G}; k_{2B}; k_{2c}; k_{2Y}; k_{2M} and k_{nR}; k_{nG}; k_{nB}; k_{nc}; k_{nY}; k_{nM}; k_{SR}; k_{SG}; k_{SB}; k_{Sc}; k_{SY}; k_{SM} are the correction factors.

If we determine the correspondence of the measurement results at - sample measurement by the correlation method; k_{1R}; k_{1G}; k_{1B} as the correction factors can be set as follows:

$$\begin{aligned}
k_{1R} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{SM}(\lambda) x(\lambda)\, d\lambda-\Delta R_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}(\lambda) x(\lambda)\, d\lambda-\Delta R_1\right]} \\
k_{1G} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{SM}(\lambda) y(\lambda)\, d\lambda-\Delta G_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}(\lambda) y(\lambda)\, d\lambda-\Delta G_1\right]} \\
k_{1B} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{SM}(\lambda) z(\lambda)\, d\lambda-\Delta B_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}(\lambda) z(\lambda)\, d\lambda-\Delta B_1\right]} \\
k_{1C} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{MS}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}\left(c_\lambda\right) c(\lambda)\, dc_\lambda-\Delta C_1\right]} \\
k_{1Y} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{MS}\left(y_\lambda\right) y(\lambda)\, dy_\lambda-\Delta Y_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}(\lambda) y(\lambda)\, d\lambda-\Delta G_1\right]} \\
k_{1M} &= \frac{\int_{\lambda 1}^{\lambda 2}\left[E_{MS}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_S\right]}{\int_{\lambda 1}^{\lambda 2}\left[E_{M1}\left(m_\lambda\right) m(\lambda)\, dm_\lambda-\Delta M_1\right]}
\end{aligned} \tag{13}$$

Using (9), (10) and (11) the k_{2R}; k_{2G}; k_{2B}; k_{2c}; k_{2Y}; k_{2M} and k_{nR}; k_{nG}; k_{nB}; k_{nc}; k_{nY}; k_{nM} can be calculated.

In the absence of correction ($k_{1R} = k_{1G} = k_{1B} = k_{1C} = k_{1Y} = k_{1M} = 1$) (9) and (11), if ($k_{2R} = k_{2G} = k_{2B} = k_{2C} = k_{2Y} = k_{2M} = 1$) and ($k_{nR} = k_{nG} = k_{nB} = k_{nC} = k_{nY} = k_{nM} = 1$) are accepted according to Equations (9) and (11), (10) and (11) respectively, the error of each measuring point can be calculated corresponding to the next point.

If substitution k_{1R}; k_{1G}; k_{1B}, k_{2R}; k_{2G}; k_{2B}; k_{11}; k_{12}; k_{13}; k_{21}; k_{22}; k_{23} and k_{n1}; k_{n2}; k_{n2} are accepted respectively, the equality condition can be written as follows (three rows, n columns and 3×n dimension). The k_{1R}; k_{1G}; k_{1B}; k_{2R}; k_{2G}; k_{2B} and k_{nR}; k_{nG}; k_{nB} of k_{11}; k_{12}; k_{13}, k_{21}; k_{22}; k_{23} and k_{n1}; k_{n2}; k_{n2}, respectively are in n column, 3×n dimension. For six channels it will 6 column or 6×n elements.

$$\begin{vmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ . & . & . \\ k_{n1} & k_{n2} & k_{n3} \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ . & . & . \\ 1 & 1 & 1 \end{vmatrix} \tag{14}$$

For instance, from the expressions we can obtain the conditions of conformity of the measurements for the following consecutive stage according to the results of the two measurements in which the RGB measurement was performed.

$$\begin{aligned}
&\Delta MR1,2 = \int_{\lambda 1}^{\lambda 2} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] x(\lambda)\, d\lambda = \Delta R_1 - \Delta R_2 \\
&\Delta MG1,2 = \int_{\lambda 3}^{\lambda 4} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] y(\lambda)\, d\lambda = \Delta G_1 - \Delta G_2 \\
&\Delta MB1,2 = \int_{\lambda 5}^{\lambda 6} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] z(\lambda)\, d\lambda = \Delta B_1 - \Delta B_2 \\
&\Delta MC1,2 = \int_{\lambda 1}^{\lambda 2} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] x(\lambda)\, d\lambda = \Delta C_1 - \Delta C_2 \\
&\Delta MY1,2 = \int_{\lambda 3}^{\lambda 4} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] y(\lambda)\, d\lambda = \Delta Y_1 - \Delta Y_2 \\
&\Delta M1M = \int_{\lambda 5}^{\lambda 6} \left[E_{SM}(\lambda) - E_{M1}(\lambda) \right] z(\lambda)\, d\lambda = \Delta M_1
\end{aligned} \tag{15}$$

Equation (14) can be calculated in accordance with $\Delta MR2,3$, $\Delta MR(n-1)$, $\Delta MR(n)$, respectively.

If we evaluate the measurement results of the RGB system at one point according to the measurement results of the product in that condition, the composition and quality of which are known as sample measurement (excluding the measurements at the second point), then the result for the first point can be evaluated as follows:

$$\Delta M1R = \int_{\lambda 1}^{\lambda 2} \left[E_{SM}(\lambda) - E_{M1}(\lambda) \right] x(\lambda)\, d\lambda = \Delta R_1 - \Delta R_2$$

$$\Delta M1G = \int_{\lambda 3}^{\lambda 4} \left[E_{SM}(\lambda) - E_{M1}(\lambda) \right] y(\lambda)\, d\lambda = \Delta G_1 - \Delta G_2 \tag{16}$$

$$\Delta MB1,2 = \int_{\lambda 5}^{\lambda 6} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] z(\lambda)\, d\lambda = \Delta B_1 - \Delta B_2$$

$$\Delta M1C = \int_{\lambda 1}^{\lambda 2} \left[E_{SM}(\lambda) - E_{M1}(\lambda) \right] x(\lambda)\, d\lambda = \Delta C_1 - \Delta C_2$$

$$\Delta MM1,2 = \int_{\lambda 5}^{\lambda 6} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] z(\lambda)\, d\lambda = \Delta M_1 - \Delta M_2 \tag{17}$$

$$\Delta MM1,2 = \int_{\lambda 5}^{\lambda 6} \left[E_{M1}(\lambda) - E_{M2}(\lambda) \right] z(\lambda)\, d\lambda = \Delta M_1 - \Delta M_2$$

where, $E_{SM}(\lambda)$ is the intensity of the input signal corresponding to the exemplary measurement of the system.

For the second and nth measurement centers (10), (11) and taking into account the exemplary measurement result (12) expressions identical to the expression will be defined (15). Based on the measurement results, ΔMR, $\Delta M1R$, $\Delta M2R$ and are calculated and the obtained results are evaluated on three limits of error, above the permissible, permissible limit and below the permissible limit.

The value and sign of MR measurement allow to evaluate whether the process is going correctly between the stages of the placed technological process of points $M1$ and $M2$. For example, the fact that $\Delta M2R0$ does not mean that the process is correct, it is possible that the measurement error at both points is approximately the same. For this reason, it is assumed that the measurement errors at each point are compared with the values considered normal for that corresponding point (for example, $\Delta_n M1R$ and $\Delta_n M2R$ for $\Delta M1R$ and $\Delta M2R$).

In this way, the error assessment is intended to be performed not only on the basis of measurement results of the optical module, but also on other parameters (TC and DTM) that characterize the object (product) in the technological process (Figure 1).

The next stage after the error assessment is to analyze the error values and determine if they are within the norm limits. Based on the results of this stage, it is necessary to evaluate the technological process and, if necessary, to improve the results by intervening in the process with the control of executive mechanisms. In the intelligent system, it is assumed that the above-mentioned processes and decision-making based on the results obtained will be carried out efficiently. The sensors being the eyes, PLCs and PCs being the brain, and executive mechanisms being the hands of the system almost completely reduce and minimize the direct involvement of man in this process, and achieve an operational solution to the problems of artificial intelligence.

The obtained conditions allow to obtain accurate measurement results by estimating the errors of the RGB measurement system carried out at two consecutive points of the process.

To evaluate the error, different temperature, density, viscosity, etc. of the product with known composition. Measurement results in accordance with technical parameters such as the intelligent system manages to ensure that the technological process results in the production of high quality products according to the limits of errors.

As a temperature sensor, the liquid crystal-based receiver is both temperature sensitive due to the nature of the polymers in the structure, and allows you to visualize the result with a change in color. As a result, by conducting a comparative analysis of the color characteristics of the product, we obtain a color map obtained by changing the composition. Measurement of other parameters - temperature and density - for each color indicator plays a supporting role in identification.

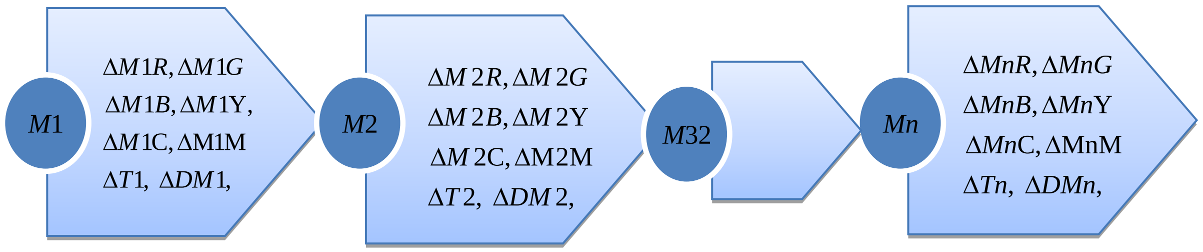

Figure 1. Evaluation of errors based on the results of *n* measurement points of the technological process for three channels

A structural model of an intelligent measurement and control system for product composition control is presented in Figure 2.

A measurement center that allows you to monitor the various stages of the process in the structure of the control system 1 and 2 (MC1 and MC2) from the appropriate temperature measurement module as described above (TMC1 and TMC2), from the module to measure density (DMC1 and DMC2), colorimetric and close for color control From an optical module that can be adjusted to measure IR ranges (OM1 and OM2), From analog and digital input modules of PLC (PLC AGM1, PLC AGM2 and PLC RGM1 and PLC RGM2) was organized. The intelligent system is also to serve the appropriate measurement center PLC CPU1 and PLC CPU2, Personal computer (PC) and visualizing data and management SCADA system, the data to be compared with the data of the corresponding measuring point database (DB1 and DB2), with the appropriate temperature and density indicator of the measured color indicator.

A memory block that allows the identifiable data to be stored in memory (DRM1 and DRM2), program memory that allows self-checking and self-correction of the system (SPM), indication panel (IP), transmission and reception block (TRB), the device and block affecting the process (in order to ensure that the parameters are within the required limits) executive mechanisms that perform management (EM1 and EM2), PLC digital output module for control of execution mechanisms through each PLC (PLC DOM1 and PLC DOM2), nominal temperature and density at each measuring point data reflecting the values of the sample measurement results at each measurement point bases (CMI1 VB1.1 and VB1.2, CMI2 VB2.1. and 2.2) and so on.

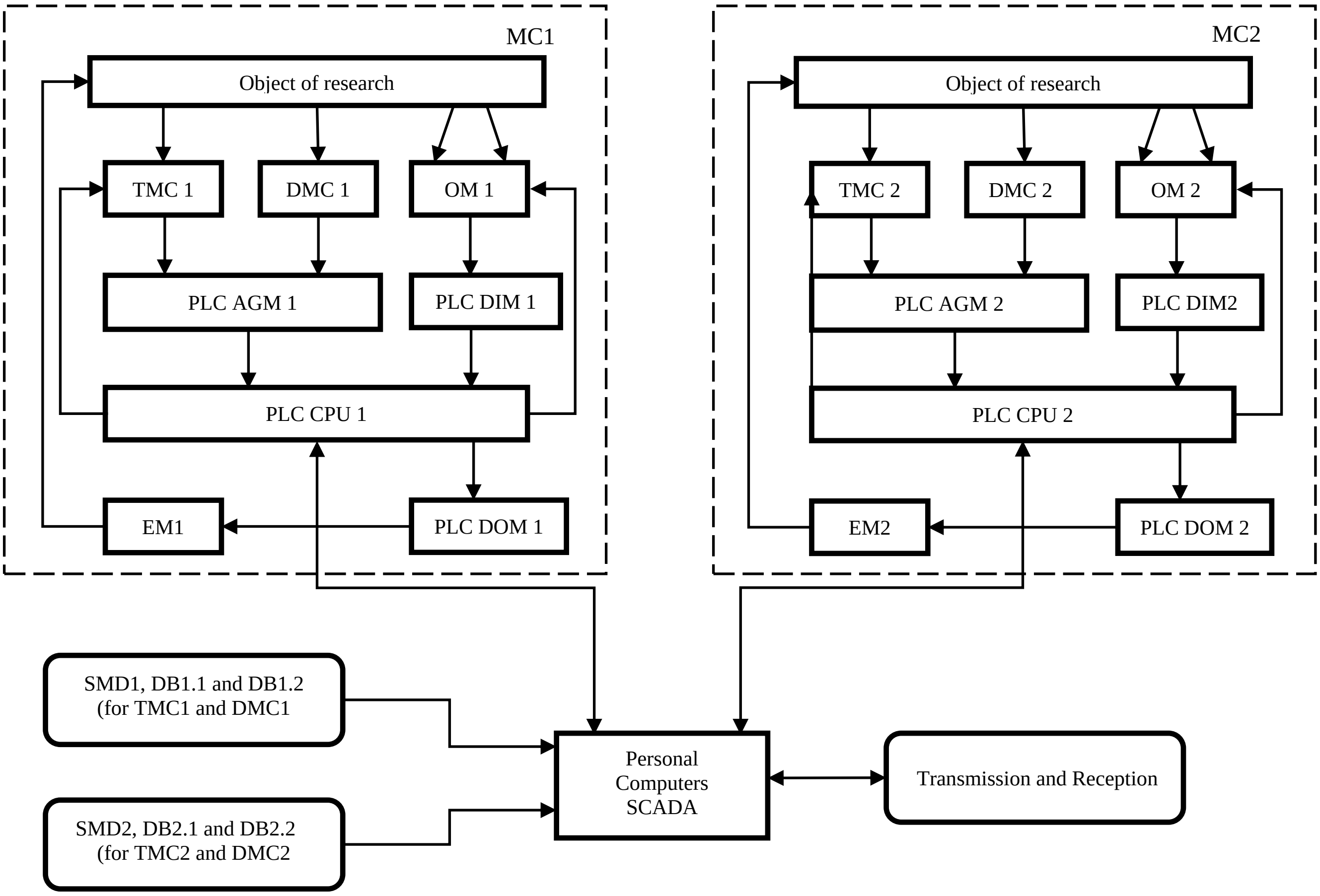

Figure 2. Generalized structure of the product composition control system

The structural model of the optical module (OM), one of the organizers of the intelligent system and used to evaluate the color performance of the product, which allows to perform colorimetric and close IR measurements, is presented in Figure 3.

As can be seen from the Figure 3, the optical module is connected to the light source to perform the study of the product of a certain stage of the technological process. (İM), from the object of research in accordance with the studied stage of the technological process (TO), from the optical receiver and converter block (ORCB), It consists of an analog input module of the PLC, PLC modules compatible with the channels PLC AIM and PLC block (PLC AIM and PLC CPU), ORCB- from liquid crystal filters such as multifunction modules such as light filters and infrared radiation receivers that control the output bandwidth and working wavelength of (MKB) and converters (ÇB) consisting of liquid crystalline blocks (LKB), a power source that allows certain frequencies and amplitudes to be set to control these blocks (PM) and from its control module (CM), from the PLC CPU module, which performs measurement, comparison and control, from its program memory (PMD), data reflecting the condition of the object (OMD) and sample measurement results (SMD) from the resident memory of the data for the organization and storage (DRM), from the comparison and decision-making block (CDB), lokal SCADA from the visualization block, from the external memory module for storage of measurement results accompanied by identifiers by time and observation point (EMM) was organized.

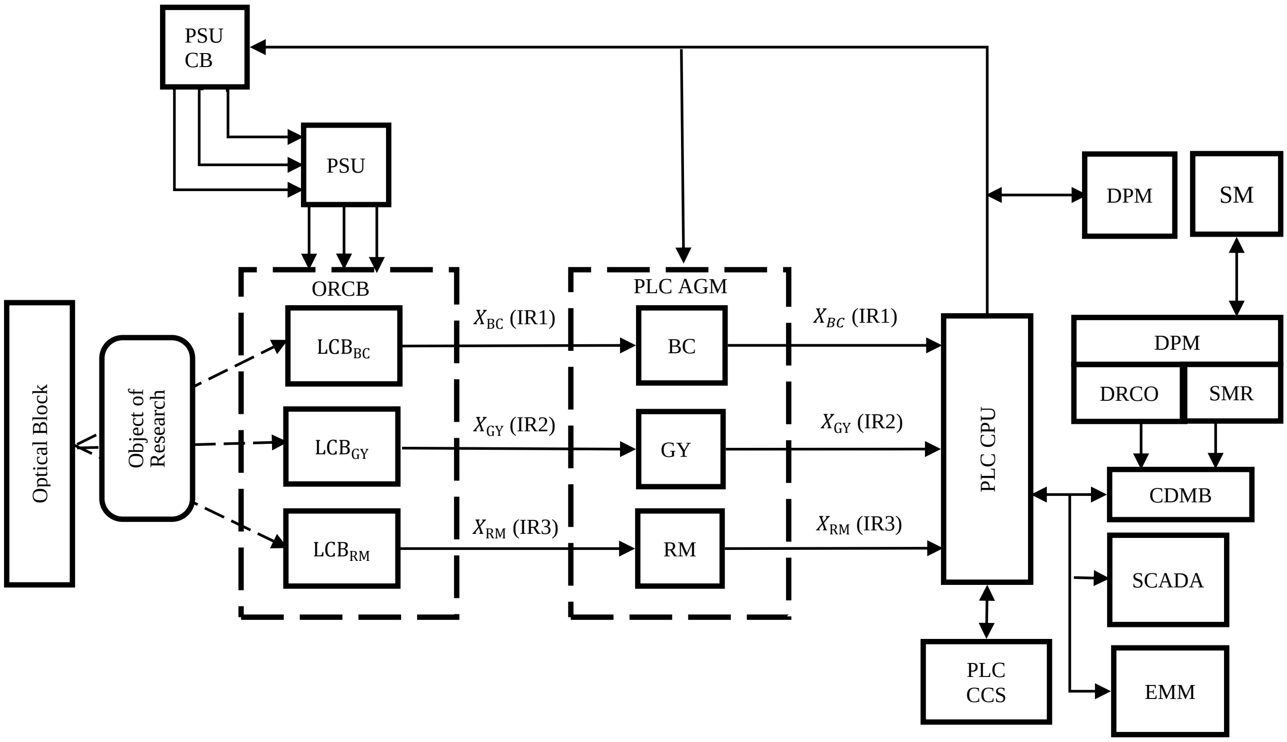

Figure 3. The principle of operation of the optical module

The optical module is visible and can operate in the near IR range, adjusting to record the corresponding IR rays from the product when the face light source is not connected. To do this, the MKS liquid crystal filter is tuned to receive signals in the same range by means of the PU control unit with the appropriate frequency signal of the QM. The measurement results are transmitted to the memory block of the corresponding OM and to the central PLC CPU. These data are used to evaluate the quality of the product by comparing the results of measurements on the visible part of the optical range with time and effective and technical parameters and comparing them with the results of sample measurements placed in the appropriate VB. In the other (colorimetric) mode of the optical module, the rays from the light source pass through the product and fall on the appropriate liquid crystal-based block of the OCD.

MKB is also a controlled liquid crystal light filter used (2) and (3). The output signals corresponding to the wavelengths of the colors in the expressions are in the converter block (CB) it is then amplified and converted to analog voltage by a photocurrent corresponding to the channels to which it is connected. The analog voltages are then transferred to the analog input module of the PLC (PLC AIM). In the optical block (OB) The PLC CPU controller block used directly measures, controls and self-monitors each channel. In the appropriate database, such as sample measurement results at each measurement point and data identified by quantities corresponding to normal technological conditions (RMD1, RMD2) stored and with current measurement results (3)-(12) are compared based on their expressions. Measurement and processing results of local observation points are simultaneously central PLC CPU or transmitted of each measuring point (M) PLC CPU.

The assessment of the error obtained in the measurement results are visualized on the SCADA control and indication panel of both the local observation (measurement) station and the central system. Based on the system self-monitoring and correction software package, the correct implementation of local measurement points and the functional model of the overall system is regularly monitored.

Frequent occurrence of errors and repetition after correction allows to identify the product according to time and parameters, such as violation of the technological process and, consequently, low quality of the product, and prompt delivery to higher hierarchies of the production process gives. Optical module used in color evaluation to increase measurement accuracy (OM) Increasing the number of measurements at wavelengths corresponding to other intermediate colors using the existing channels by increasing the number of liquid crystal filters and half-bands is carried out by the PLC CPU of the local observation point by adjusting the control frequency of the block in accordance with the intermediate colors.

The central PLC CPU module performs the central brain function of the entire system by implementing distributed control in this type of structural model. As can be seen in the algorithm for developing a color control system for petroleum products, the initial data are entered first. After entering the initial data, the light source is selected. The beams are then filtered and information is obtained according to the standard product and the product under study by means of a colorimetric block. The standard product is compared with the product under study. If an error occurs, execution mechanisms that can affect characteristic parameters of process are controlled.

The algorithm of the functional model of the intelligent measurement and control system of product quality during the process is presented in Figure 4.

The comparison of the data obtained on the color of the product and the data of the corresponding database reflecting the quality of the product is also analyzed based on the identification of other contact measurement results, temperature and density measurement results performed at each step. Relevant changes are information carriers as error, and as shown in the block diagram, error assessment, additional measurements at wavelengths corresponding to intermediate colors in the working range, control of execution mechanisms that allow changing known quantities of the process are automatically automated as intelligent system self-assessment, correction, measurement, and control performed.

For a short sequence of the process, the simulation of the management and control process and its reflection in SCADA are presented.

The operating algorithm of the used simulator device consists of 5 parts: 1) SCAN the inputs; 2) Data processing; 3) Transfer the result to the output; 4) Establish an online connection with SCADA; 5) Control of enforcement mechanisms.

- SCAN input

The control module of the simulator is based on the Arduino Mega.

The SCAN subroutine constantly scans data (discrete and analog signals) from tumblers and potentiometers that mimic the parameters of the valve, pump and NOC connected to the control module. Scanned parameters are written to the appropriate variables to be processed.

- Data processing

The scanned parameters are processed in the PROCESSING subroutine after being written to the appropriate variables. Occurs as a processing cycle. The processing process changes depending on each new scan parameter.

It controls the opening/closing of the valves, the pumping on / off, the level in the tanks, the pressure in the measuring line, the temperature, the flow. In addition, it monitors the discharge of the first items in the main jaw with the appropriate dose until the appropriate substance is obtained. Prepares the result for the speech, depending on the task. MODBUS / RTU protocol, which meets international standards.

- Transmission of the result to the output

After processing the result in the processing process, it is transferred to the RESULT subroutine. Depending on the result, the appropriate speeches are activated and deactivated. Direct control of valves, pumps, heaters is performed.

- Creating an online connection with SCADA

The simulator is equipped with SCADA software for viewing results and remote control. The INTERFACE subroutine is used to connect to SCADA on a personal computer. The communication protocol is based on the.

Connecting the temperature and pressure sensors used in the auxiliary transmitter block to the microcontroller module according to the diagram and using a resistor with appropriate resistance (250 Ohm) to read the measurement results and converting the obtained signal into 1-5 V voltage range results in controller analog input pins. The indicators on the 16×2 LCD display reflect the change in the output signals of the sensors.

- The essence of the matter

It consists of an imitation of a reflective and automatic control system obtained during the preparation of a product with a certain composition during the technological process. Thus, chemical reagents can have different components. We will look at the technology of preparation of a 2-component reagent. Figure 5 presents the SCADA simulation model of process execution in two colors.

The components are pumped from the machines to the corresponding TANK 1 and TANK 2 by means of the pump 1 by opening the valve 1 - the valve 5 and the valve 6 - the valve 2, respectively. Depending on the composition of the chemical reagent, a certain dose is injected from TANK 1 and TANK 2 into TANK 3 reagent. A new reagent is prepared by heating the TANK 3 reagent tank to a certain temperature. The pressures at the outputs of the pumps are controlled, the level in TANK 1 and TANK 2, and both level and temperature in TANK 3. Levels are alerted with an indicator when they exceed 80%.

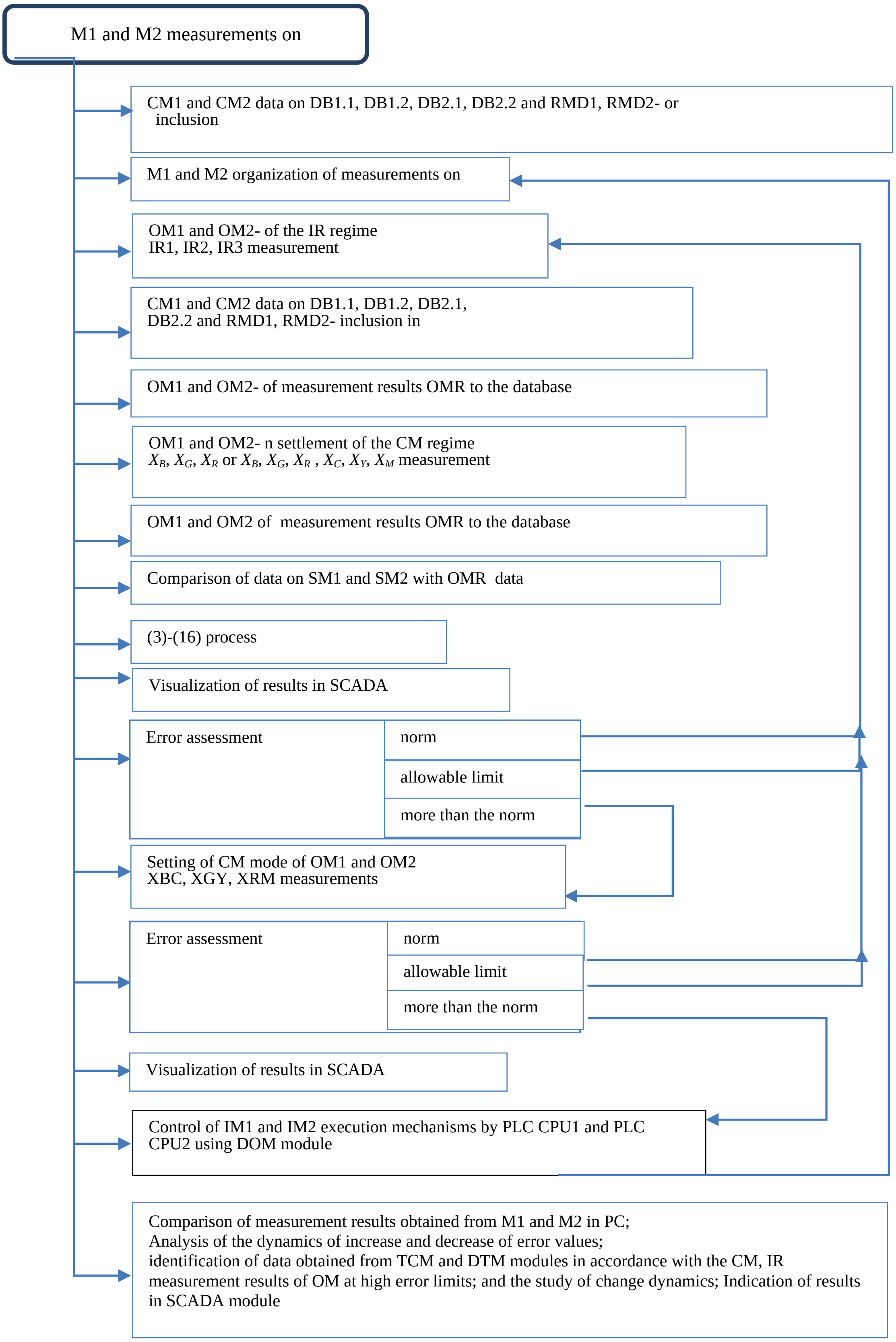

Figure 4. Algorithm of functional model of intelligent measurement and control system.

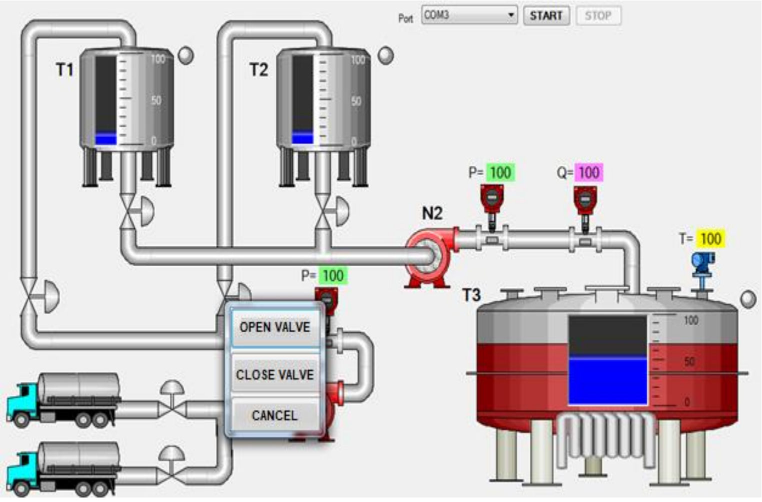

Figure 5. SCADA simulation model of process execution in two colors

3. CONCLUSION

A structural and functional model of a PLC and SCADA-based intelligent measurement and control system has been developed to directly assess product quality in the production process with high accuracy. The main contribution here is to determine the quality and quantity of elements in the product by optical analysis methods to determine the results at important stages of the process, taking into account the influence of other internal and external factors that affect quality, for example, temperature. differences in composition

Advantages:

Under the condition that the number of channels does not change, make measurements at wavelengths corresponding to other intermediate colors of the working range of the electromagnetic spectrum;

Self-control, management and correction;

Measurement - performance of control and monitoring directly during the process;

The ability to quickly evaluate the error and increase the accuracy of the results.

The proposed algorithm, structural and functional model allows for simultaneous comparison of control and measurement results at different stages of the process ($M1$, $M2$ and Mn), real-time detection of possible deviations, self-monitoring, system reconstruction and required system corrections gives Based on the results, it is decided to perform the measurement process according to the three or six sub-bands of the visible range, and for this purpose, these measurements are automatically adjusted by controlling the OM unit of the system. In order to obtain alternative results in the control of product composition, one can decide on the mode of making measurements in the infrared range in the OM.

At this time, the evaluation of errors and the analysis of the norms established in the database allow to improve the results by influencing the process when necessary.

The intelligent system is designed to perform the above-mentioned processes and make decisions based on the obtained results, which is an important condition for the digital industry, the smart industry.

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BIOGRAPHIES

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