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Diesel Fuel Quality Monitoring System based on Genetic Algorithm

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ABSTRACT This article highlights determination of diesel fuel quality indicators by electrical method using the electrical measurements frequency range of the measuring transducer amplitude characteristics for diesel fuel. A method is proposed that allows controlling the quality of fuel by the characteristics of a high-frequency electromagnetic signal passed through the fuel under study. The relationship between the electrical parameters and physical parameters of diesel fuel is determined, which can be traced in measurements and graphs. This control system is represented by a function that has several conflicting criteria that need to be optimized simultaneously, so the approximation method is applied as the most successful option for the study. A cubic polynomial is used to approximate the given dependence. To extend the approximation capabilities of the polynomial, the integer powers of x are substituted by real ones. The dependence of the measured and approximated values is analyzed and the differences between them are estimated.

KEYWORDS control system; diesel fuel; genetic algorithm; approximation; cubic polynomial.

I. INTRODUCTION

MODERN transport energy is predominantly based on oil fuels. In recent years, the Ukrainian market has seen significant changes in the range of motor gasoline, diesel fuel and oils. New brands of oil fuels with better environmental properties have appeared due to the spread of destructive oil refining processes, especially hydrocatalytic ones, as well as the use of effective additives that improve physical, chemical and operational properties of oil products, and the import of fuel from abroad.

For users of automotive diesel fuel (EN 590:2009 standard), the stability of its parameters is a very important issue [1]. The stability of diesel fuel can be analyzed from the point of view of the producer, distribution network and the end user and is directly related to its composition [2]. Determining the indicators of diesel fuel on which its quality depends is a crucial procedure [3]. Since the diesel fuel has indicators that most accurately characterize the quality of the diesel fuel, there are indicators that can reach the maximum limit (cetane number) [4-7] and those that can reach the minimum limit (sulphur). In this case, it is believed that diesel fuel, according to a certain optimality coefficient, acquires the characteristics of high quality. The analysis of such a control system is carried out by determining the main quality indicators of diesel fuel and has a developed scale of quality characteristics. The use of the laboratory methods for determining the quality indicators of diesel fuel is outdated in the age of computerization, time-consuming and long-term. Therefore, electrical methods of controlling diesel fuel are of wide interest.

Scientific research of the control system using electrical methods with the use of a capacitive sensor in wide frequency ranges of the electromagnetic field allows faster determining the dependence on the chemical nature of fuel and the fuel quality. Research of new methods using optimization problems makes it possible to find the dependence of electrical parameters of fuel on its composition, which is reduced to the problem of parametric optimization.

Objectives of the study are as follows: to analyze the electrical method of the control system of diesel fuel from different importing countries in terms of their electrical parameters; to build a mathematical model of the control system of diesel fuel and study it using a genetic algorithm; to compare the differences between the obtained result and the desired one.

II. LITERATURE REVIEW

Diesel fuel is often monitored using mathematical calculations. However, such calculations can change the final results, as information on congestion, road conditions and many other parameters is constantly updated. So, the determination of whether the results of the mathematical formula and reality correspond to each other may not coincide or be close to the benchmark, as it is impossible to check the situation on the road in most cases. Therefore, the approximate mathematical method can often be called an effective and useful for determining the diesel fuel control. For the control, the measured fuel quality indicators are used, which are collected for calculations. In [8], automatic data collection was used, which largely eliminates human errors during data entry and prevents post-adjustment of the mission success or failure. Unique aspects of this work include automated data collection, analysis, and storage, creating standardized record for all vehicles and events. This greatly reduces the effort required for reporting and analysis. This analysis showed reliability in customers' experience. Also, over the past few decades, research interest in green data centers (GDC) in the cyber-physical system has increased dramatically [9]. The excessively growing need for information and communication technologies and the gigantic demand for Internet data services may lead to an increase in the number of data centers, resulting in huge electricity costs for GDC. Based on the properly collected and processed fuel values, modelling was carried out, focusing on the optimal system architecture and the corresponding evaluation of scenarios over a wide range. The modelling and evaluation approach was introduced to compare a diesel engine with several battery-electric tyre systems and allowed the significance of each system component to be determined. The impact on both engine performance and the environment were assessed. The transition from fossil fuel vehicles to emission-free vehicles is gaining momentum in public transport [10]. Transport companies face challenges of increased complexity in determining the optimal system approach and choosing the most appropriate technology. CO2 emissions have been reduced by at least two-thirds, while the remaining emissions are mainly the result of battery production. The use of auto rickshaws, which is an important paratransit mode of urban transport in India [11], showed that CO2 and NOx emissions were higher in the 12-30 km/h speed range, while NOx emissions were found in the higher 30-40 km/h speed range. Improving vehicle flow and reducing frequency of sudden accelerations and decelerations can curb emissions and reduce fuel consumption. Environmental sustainability in the aviation industry is becoming a subject of research and concern [12]. Reducing the carbon footprint is becoming necessity as natural resources are being depleted faster than they are being created. Diesel exhaust fluid effectively reduces the emissions of the two most important components of diesel exhaust gases, particulate matter and NOx.

In addition to the environmental problems caused by use of fossil fuels, which are limited in supply and highly volatile in price, it is worth focusing on the development of renewable energy sources, such as biodiesel, which helps reduce greenhouse gas emissions [13]. The use of biodiesel instead of petroleum diesel fuel and its representation by a genetic algorithm will be investigated in future publications. In the meantime, the hybrid optimization model software for diesel fuel, which was used for the simulations, focuses on the optimal analysis and investigation of diesel fuel control system.

A control system is a concept of inspection systems which applications range from industrial control systems to the control of large physical experiments [14, 15]. To study a control system, it is necessary to perform mathematical modelling and analysis using the concept of hybrid systems [16]. Computational processes in such a system are considered as systems with discrete events, which can be conveniently modelled using a number of approaches focused on optimal analysis using a genetic algorithm [17]. Optimal analyses are optimization problems that must determine the best solution to fulfil constraints and maximize or minimize an objective function. In general, algorithms were developed to solve these complex problems - a combination of natural approaches with specialized stochastic operators [18, 19].

III. DETERMINATION OF DIESEL FUEL QUALITY INDICATORS

The diesel fuel quality control system includes determination of diesel fuel quality indicators, determination of diesel fuel quality control methods, selection of diesel fuel life cycle stage, which constitute the diesel fuel quality assurance system, which allows assessing the quality of diesel fuel by selected control methods using computational algorithm and mathematical models, taking into account the requirements of regulatory documentation. The procedure for studying diesel fuel quality control is very complex and multifaceted. It requires the use of both modern mathematical tools and deep practical knowledge and experience. Therefore, in order to simplify the laboratory procedure of diesel fuel quality control, we propose mathematical and electrical approaches to obtain this quality. Namely, the control system will be analyzed and investigated by electrical and mathematical methods or algorithms.

The electrical measurement method is a method of determining the physical parameters of an object by converting them into an electrical signal. This method uses the principles of electricity for accurate and fast measurement, which allows reducing the influence of external factors and increasing the reliability of the obtained data. Usually, the measurement process involves the use of transducers that respond to changes in the measured value and generate the corresponding electrical signal. Then this signal is processed with the help of electronic devices, which allows us to get the value of the measured value in real time. Electrical methods of measuring non-electrical values (quality indicators of finished products and raw materials) are widely used in study of products and services in the era of computerization and the use of artificial intelligence and machine learning. The conversion of non-electrical quantities into electrical signals is carried out using measuring transducers. Electrical methods such as capacitive, induction, etc. are widely used to measure non-electrical quantities.

An electrical method for control the quality of fuel under study was developed using the frequency range of electrical measurements of the amplitude characteristics of the measuring transducer for diesel fuel [20]. The proposed method makes it possible to control the quality of fuel by the characteristics of a high-frequency electromagnetic signal passed through the fuel under study. The electrical method of diesel fuel quality control consists in development of a measuring electrical circuit that allows recording changes in the characteristics of electromagnetic signal depending on the type of fuel under study.

To determine the effect of the fuel under study on the characteristics of the output signals of the measuring transducer, a sinusoidal periodic high-frequency signal is fed from the output of the oscillator to the input of the measuring transducer. An electromagnetic sinusoidal high-frequency signal is applied from the oscillator output to the measuring transducer, which is a series-connected resistance store Rn and a capacitive sensor Cx, between the covers of which the fuel under test is located, an electromagnetic sinusoidal signal of high frequency is fed from the oscillator output.

The fuel under test, which is located between the capacitor covers, changes the amplitude-frequency response of a sinusoidal signal applied to the capacitor plates in a certain frequency range.

The electrical circuit of the fuel test is shown in Figure 1.

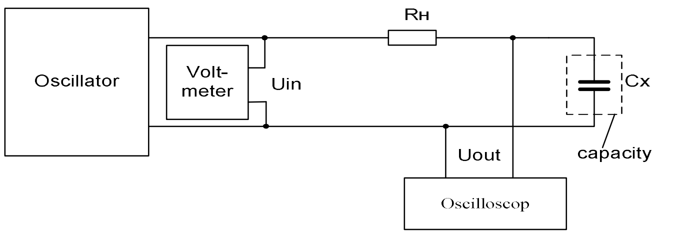

Figure 1. Electrical diagram of fuel analysis using a capacitive sensor.

The electrical circuit is designed to obtain experimental diesel fuel data from various importing countries. It contains an oscillator, a voltmeter, an oscilloscope, a resistance box and a test object. The test object consists of a 0.75-litre container and a capacitive sensor made of textolite metallized with a thin copper layer with a plate width of 67 mm, plate length of 119 mm and plate spacing of 1.4 mm. A voltmeter, a series converter, and an oscilloscope are connected to the oscillator in parallel.

The input voltage (Uin) on the voltmeter is set to 5V and kept constant throughout the measurement.

After some calculations, and taking into account that sensor capacity under operating conditions is 0.11nF, it is recognized that the nominal resistance of the circuit will be 1.5kΩ, which is set on the resistance store. The frequency on the oscillator varies from 500kHz to 10MHz. The oscilloscope reads the output voltage (Uout).

The research sequence is as follows. The test circuit is connected to the power supply, the container is filled with the test fuel, into which the capacitive sensor is installed, and experimental studies are carried out for this test fuel. In this way, the voltage Uout for the test fuel is determined at frequencies from 500 kHz to 10 MHz for each sample. The results of the experimental studies, i.e., the measured values of the output voltage and the steady-state value of the input voltage from frequency changes, are stored to determine the reduced output voltage value Unp.

The reduced output voltage value Unp of the signal under test is determined by the following formula:

$$U_{np} = \frac{U_{out}}{U_{in}}, \tag{1}$$

where Uout – output voltage readings taken from the oscilloscope; Uin - input voltage, which is set on a voltmeter and kept constant (Uin = 5V).

The results of calculating the reduced value of the investigated signal Unp are shown in Table 1. According to the table, a graphical representation of the reduced value of the investigated signal versus frequency is constructed and conclusions about the quality of the investigated fuel are drawn.

Table 1. Results of the diesel fuel experimental research

f, MHz	Romania	Lithuania	Poland
	Unp	Unp	Unp
0.5	0.38	0.38	0.4
0.8	0.68	0.66	0.66
0.9	0.76	0.72	0.76
1	0.84	0.8	0.84
2	0,6	0.6	0.58
3	0.66	0.66	0.7
4	0.46	0.48	0.48
5	0.44	0.4	0.4
6	0.32	0.3	0.3
7	1.2	1.16	1.16
8	2.16	1.56	1.52
9	1.52	1.32	1.24
10	1.24	1.28	1.2

The dependence of the reduced value Unp of the measuring transducer for diesel fuel from different importing countries on the frequency f according to Table 1 is shown in Figure 2.

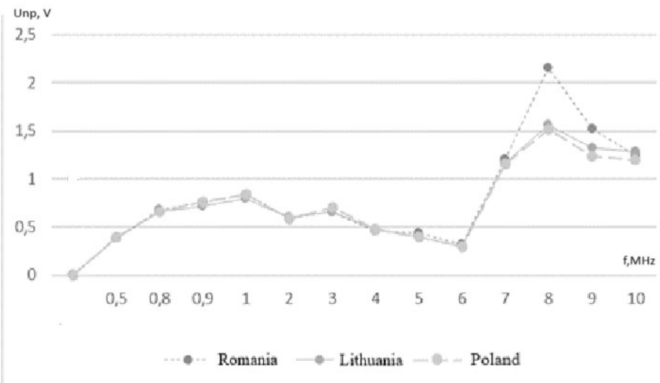

Figure 2. Dependence of the reduced value Unp of the measuring transducer for diesel fuel from different importing countries on the frequency f.

The graphs show that all the dependencies of the reduced value Unp of the measuring transducer for diesel fuel from different importing countries have different reduced signal values at a frequency of 8 MHz. The dependence of the amplitude A for diesel fuel from Romania has the highest reduced signal value. This may indicate that this diesel fuel has different quality values than the other diesel fuels.

The relationship between the electrical parameters and the physical parameters of the diesel fuel can be seen in the measurements and graphs. Electrical parameters, like physical parameters, can be represented in the form of mathematical apparatus or algorithm using modern computerization, machine learning and artificial intelligence approaches. The diesel fuel control system depends on the main indicators of the fuels under study, which can be selected for mathematical and computer processing. The generalized quality function P of any type of product is presented as a mathematical tool, and the evolutionary method of function approximation by real polynomials is used as a computerized tool.

On the basis of the systematic approach, mathematical apparatus, theory of qualimetry and taking into account the concept of electrical control, the generalized quality function P of any type of product can be represented by the functional dependence [21, 22]:

$$P = F\left[\overline{X}(Q_1, Q_2, Q_3, \dots Q_n); q_1, q_2, q_3, \dots q_n\right], \quad (2)$$

where $\overline{X}$ – a set of electrical parameters; $Q_1, Q_2, Q_3, \dots, Q_n$ – single indicators of product quality; $q_1, q_2, q_3, \dots, q_n$ – weighting coefficients of the respective single indicator.

That is, the set of electrical parameters is a function of the single quality indicators of any object under control.

If a substance or material is introduced by a bipolar sensor, its complex conductivity in the volume of the sensor's sensing element depends on the electrical parameters of the bipolar sensor. At constant values of the frequency, shape and amplitude of the test signal, in the absence of the influence of uninformative imitation, the conductivity will be as follows (3):

$$Y = F_2(X_1, X_2, \dots, X_n), \quad (3)$$

where $X_1, X_2, \dots, X_n$ – electrical parameters of the complex conductivity represented by a known substitution scheme.

If the relationship between the electrical parameters and the unit parameters of the product is known, i.e.,

$$X_1 = F_1(Q_1);\ X_2 = F_2(Q_2);\ \dots,\ X_n = F_n(Q_n), \quad (4)$$

we can record that

$$P = F\,(X_1, X_2, \dots, X_n). \quad (5)$$

Thus, the product quality function can be determined by a set of electrical parameters of the bipolar, which gives grounds for the use of electrical quality control of products, which can be represented as a bipolar. In other words, to study diesel fuel quality control system, measuring instruments can be used that measure the signal amplitude depending on the frequency and represent it as a mathematical dependence. Expression (5) shows the functional dependence of diesel fuel quality indicator on their electrical parameters.

Now, it is necessary to apply the evolutionary method of approximating functions by real polynomials to expression (5) [23-29]. That is, if the input information is a set of discrete values of the argument and function, the main focus of this approach is to approximate the functions using real polynomials, which provide more flexibility in different scenarios. This mathematical algorithm is reduced for solving a parametric optimization problem to minimize the difference function between the obtained result and the desired one. This algorithm does not require any prior knowledge of the objective function or its derivatives, so it is applicable to a wide range of problems, such as those involving black box functions.

IV. APPROXIMATION OF DIESEL FUEL CHARACTERISTICS USING GENETIC ALGORITHMS

Since the diesel fuel control system is a set of elements (electrical or physical parameters) and an established relationship between them, which is represented by the dependence of the reduced signal value on frequency (Figure 2), the study of this control system is reduced to approximating the function using real polynomials. This control system can be represented by a function that has several conflicting criteria that need to be optimized simultaneously and in this case approximation method is the most appropriate option for research.

To approximate a dependence (5), a cubic polynomial can be used:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \quad (6)$$

and the following coefficients a_0, a_1, a_2 and a_3 can be found that would allow us to find a solution close to the desired one. To extend the approximation capabilities of the polynomial, we substitute the integer powers at x on real powers n_1, n_2 and n_3, respectively. Then expression (6) can be written as follows:

$$y = a_0 + a_1 x^{n_1} + a_2 x^{n_2} + a_3 x^{n_3} \quad (7)$$

This is done to find the closest possible solution by finding the powers of n_1, n_2 and n_3, that are unknown.

We need to find the values of the polynomial coefficients that will reproduce the graph as closely as possible (Figure 2). As a result, we get a system of four linear algebraic equations [30]:

$$\begin{cases} y_1 = a_0 + a_1 x_1 + a_2 x_1^2 + a_3 x_1^3 \\ y_2 = a_0 + a_1 x_2 + a_2 x_2^2 + a_3 x_2^3 \\ y_3 = a_0 + a_1 x_3 + a_2 x_3^2 + a_3 x_3^3 \\ y_4 = a_0 + a_1 x_4 + a_2 x_4^2 + a_3 x_4^3 \end{cases} \quad (8)$$

by solving which we will find a_0, a_1, a_2 and a_3. Then we can write general mathematical dependence in the form of expression (7), taking into account the found coefficients.

To find the approximation coefficients, it is necessary to group the resulting data of the reduced value Unp for diesel fuel from different importing countries from the change in frequency fi (Table 2) and this function will take the form $A(f)$.

Table 2 Resulting data

f_i	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}
f, MHz	**0**	**0,5**	**0,8**	**0,9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A_{Pi}	0	0,38	0,68	0,76	0,84	0,6	0,66	0,46	0,44	0,32	1,2	2,16	1,52	1,24
$A_{Лi}$	0	0,38	0,66	0,72	0,8	0,6	0,66	0,48	0,4	0,3	1,16	1,56	1,32	1,28
$A_{Пi}$	0	0,4	0,66	0,76	0,84	0,58	0,7	0,48	0,4	0,3	1,16	1,52	1,24	1,2

Taking into account the graph presented in Figure 2, namely the part of the graph where diesel fuel from different countries has almost the same reduced value, it is worth dividing it into two intervals. One interval is the dependence of the reduced value at a frequency from 0 MHz to 6 MHz, the second - at a frequency from 6 MHz to 10 MHz. The main manipulations will be carried out with the first part of the graph, since it most successfully reflects the sinusoidal signal and carries more information for the possibility of reproduction and approximation.

The function $A(f)$ can be written as:

$$A(f) = a_0 + a_1 f + a_2 f^2 + a_3 f^3 \tag{9}$$

Derivative $B(f)$ from this function $A(f)$ is as follows:

$$B(f) = a_1 + 2a_2 f + 3a_3 f^2 \tag{10}$$

Hence, the system of equations for calculating the coefficients a_0, a_1, a_2 and a_3 is written as:

$$\begin{cases} A_0 = a_0 + a_1 f_0 + a_2 f_0^2 + a_3 f_0^3 \\ A_9 = a_0 + a_1 f_9 + a_2 f_9^2 + a_3 f_9^3 \\ B_0 = a_1 + 2a_2 f_0 + 3a_3 f_0^2 \\ B_9 = a_1 + 2a_2 f_9 + 3a_3 f_9^2 \end{cases} \tag{11}$$

For diesel fuel from the importing country Romania $A_0 = 0, A_9 = 0{,}32$.

Respectively, $B_0 = (A_1 - A_0)/(f_1 - f_0) = (0{,}38 - 0)/(0{,}5 - 0) = 0{,}76$, and

$$B_9 = (A_9 - A_8)/(f_9 - f_8) = (0{,}32 - 0{,}44)/(6 - 5) = -0{,}12$$

Substituting the values found A_0, A_9, B_0, B_9 into the system (11), this system looks like (12):

$$\begin{cases} 0 = a_0 \\ 0{,}32 = a_0 + 6a_1 f_9 + 36a_2 f_9^2 + 216a_3 f_9^3 \\ 0{,}76 = a_1 \\ -0{,}12 = a_1 + 2a_2 f_9 + 3a_3 f_9^2 \end{cases} \tag{12}$$

Substituting a_0 i a_1 in equation (11) and replacing the fixed powers 1, 2 and 3 with b_1, b_2 and b_3 respectively, we obtain the system of equations (13):

$$\begin{cases} A_0 = 0 + 0{,}76 f_0^{b_1} + a_2 f_0^{b_2} + a_3 f_0^{b_3} \\ A_9 = 0 + 0{,}76 f_9^{b_1} + a_2 f_9^{b_2} + a_3 f_9^{b_3} \\ B_0 = 0{,}76 + b_2 a_2 f_0^{b_2 - 1} + b_3 a_3 f_0^{b_3 - 1} \\ B_9 = 0{,}76 + b_2 a_2 f_9^{b_2 - 1} + b_3 a_3 f_9^{b_3 - 1} \end{cases} \tag{13}$$

Since, $a_0 = 0$, i $f_0 = 0$, then the system of equations (13) is as follows (14):

$$\begin{cases} A_9 = 0 + 0{,}76 f_9^{b_1} + a_2 f_9^{b_2} + a_3 f_9^{b_3} \\ B_9 = 0{,}76 + b_2 a_2 f_9^{b_2 - 1} + b_3 a_3 f_9^{b_3 - 1} \end{cases} \tag{14}$$

Hence,

$$a_2 = (A_9 - 0{,}76 f_9^{b_1} - a_3 f_9^{b_3}) / f_9^{b_2}$$

Then $B_9 = 0{,}76 + (b_2 \ f_9^{b_2 - 1} / f_9^{b_2})(A_9 - 0{,}76 f_9^{b_1} - a_3 f_9^{b_3}) + b_3 a_3 f_9^{b_3 - 1}$

After substitution:

$C_0 = B_9 - 0{,}76$, $C_1 = b_2 \ f_9^{b_2 - 1} / f_9^{b_2}$, $C_2 = A_9 - 0{,}76 f_9^{b_1}$, then

$$C_0 = C_1 (C_2 - a_3 f_9^{b_3}) + b_3 a_3 f_9^{b_3 - 1},$$

$$C_0 - C_1 C_2 = a_3 (b_3 f_9^{b_3 - 1} - C_1 f_9^{b_3}) \ .$$

Hence, a_3 is as the following:

$$a_3 = (C_0 - C_1 C_2) / (b_3 f_9^{b_3 - 1} - C_1 f_9^{b_3})$$

Let, $b_1 = [0{,}1 \div 2]$; $b_2 = [1 \div 3]$; $b_3 = [2 \div 4]$.

Now, we find a_2 and a_3, b_1, b_2 and b_3 using a genetic algorithm (GA) and write the function $A(f)$ with the found values, and also draw a graph of the approximated function.

After applying the GA, we will get the following results: a_0 = 0, a_1 = 0,76, a_2 = 6,0710, a_3 = - 6,3197, respectively b_1 = 1,0595,, b_2 = 2,2833, b_3 = 2,2682.

Function $A(f)$ is as the following:

$$A(f)_P = 0{,}76 f^{1{,}0595} + 6{,}0710 f^{2{,}2833} - 6{,}3197 f^{2{,}2682}$$

And the graph of the approximated function is as follows (Figure 3):

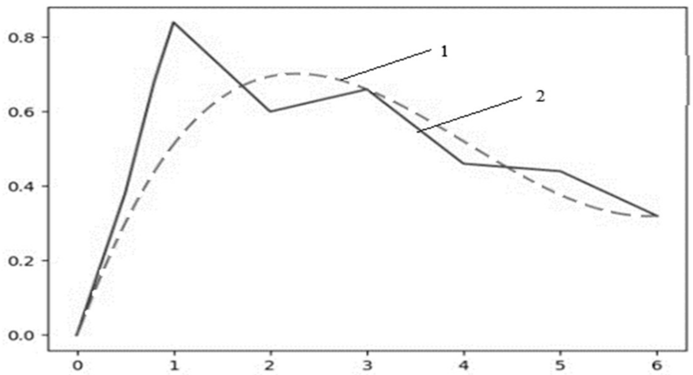

Figure 3. The graph of the approximated function (1 – dependence of the reduced value of Unp of diesel fuel measuring transducer from the importing country Romania on the frequency f; 2 – dependence of the calculated value by GA on the frequency f)

For diesel fuel from the importing country Lithuania, the results are as follows: a_0 = 0, a_1 = 0,76, a_2 = -33,3933, a_3 = 33,1443, respectively b_1 = 1,0588,, b_2 = 2,2717, b_3 = 2,2745.

Function $A(f)$ is written as:

$$A(f)_{Л} = 0{,}76f^{1{,}0588} - 33{,}3933f^{2{,}2717} + 33{,}1443f^{2{,}2745}$$

And the graph of the approximated function is as follows (Figure 4):

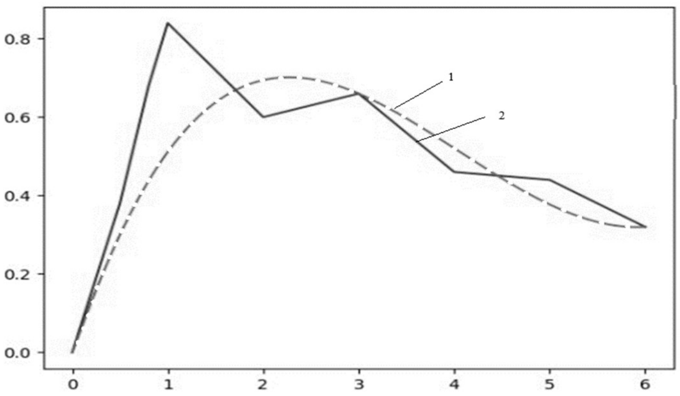

Figure 4. The graph of the approximated function (1 – dependence of the reduced value of Unp of diesel fuel measuring transducer from the importing country Lithuania on the frequency f; 2 – dependence of the calculated value by GA on the frequency f)

For diesel fuel from the importing country Poland, the results are as follows: a_0 = 0, a_1 = 0,76, a_2 = 1,5953, a_3 = -1,8376, respectively b_1 = 1,0766,, b_2 = 2,3678, b_3 = 2,3131.

Function $A(f)$ is written as:

$$A(f)_{Л} = 0{,}76f^{1{,}0766} + 1{,}5953f^{2{,}3678} - 1{,}8376f^{2{,}3131}$$

And the graph of the approximated function is as follows (Figure 5):

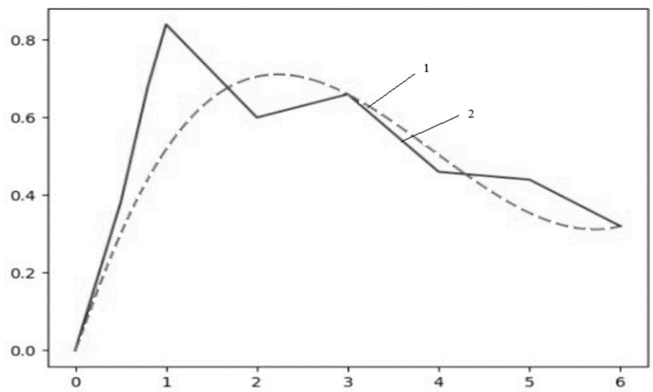

Figure 5. The graph of the approximated function (1 – dependence of the reduced value of Unp of diesel fuel measuring transducer from the importing country Poland on the frequency f; 2 – dependence of the calculated value by GA on the frealgebquency f).

If we substitute the boundaries $[b_1 - b_3] = [0 \div 5]$, then the results will be: a_0 = 0, a_1 = 0,76,a_2 = 6,1596, a_3 = -6,2143, respectively b_1 = 0,9983,, b_2 = 0,6654, b_3 = 0,7661. And the graph of the approximated function is as follows (Figure 6):

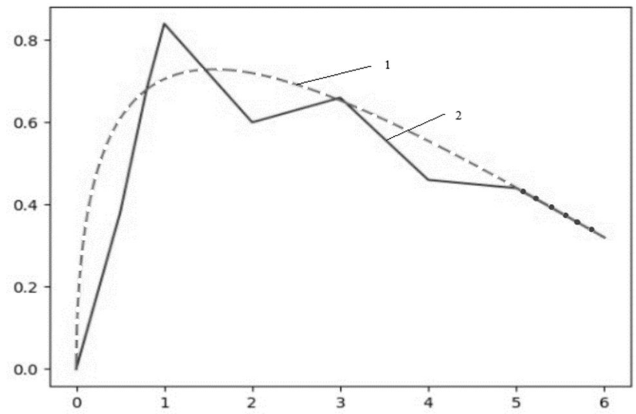

Figure 6. The graph of the approximated function (1 – dependence of the reduced value of Unp of diesel fuel measuring transducer from the importing country Romania on the frequency f; 2 – dependence of the calculated value by GA on the frequency f).

Since the input to the approximated function is a set of discrete values of the argument and function, the main focus is on an approximated function that is approximately equal to the measured function and that gains flexibility in different scenarios. This algorithm does not require any prior knowledge of the objective function or its derivatives, so it is suitable for a wide range of problems, including those involving black-box functions. This can be seen in the graphs shown in Figs. 3-5. These representations show the discrepancies between the obtained result and the desired result, which characterize the permissible deviations, since each measurement may have an error. The graph in Fig. 6 has slightly different approximation limits and, accordingly, the approximation graph looks different. Comparing the graphs in Fig. 3 and Fig. 6 for fuel from the same importing country, it is clear that the latter has a closer approximation curve to the measured curve. At higher frequencies, the two curves coincide. This makes it possible to argue that it is worth applying GA within the limits of $[b_1 - b_3] = [0 \div 5]$, then the approximated function will better reflect the expected result.

V. CONCLUSION

The procedure for testing the diesel fuel control system can be carried out either electrically, which requires a circuit diagram and fuel samples, or by mathematical modelling. In the latter case, it is sufficient to have the fuel values and their permissible tolerances. As a mathematical model of the diesel fuel control system, the article proposes a functional dependence of diesel fuel quality on their electrical parameters. To study this model, the function is approximated by real polynomials using a genetic algorithm. The modelling results presented in the graphs allow us to analyze the dependence of the measured and approximated values, assess the differences between the result obtained and the desired one, analyze them and determine the limits within which it is better to apply the genetic algorithm.

To improve the approximation results, it is necessary to have a larger number of empirical values $A(f)$.

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