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THE INCREASE OF ENERGY AND ENVIRONMENTAL EFFICIENCY AND RELIABILITY OF POWER EQUIPMENT BY COMPREHENSIVE MONITORING OF ITS ACTUAL STATE

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This paper is devoted to the reliability improvement, increase and efficiency of evaluation methods of energy efficient equipment by implementation of comprehensive parametric identification of actual characteristic of the energy object to enhance aggregate energy efficiency and environmental reliability level. It was designed and implemented the complex technology of parametric identification of the energy object actual characteristics: algorithms, flowcharts and methods of determination of energy facilities effective operation on example of gas pumping units and boiler, software for automated control systems the actual characteristics. The real tests of comprehensive parametric identification of actual characteristic are conducted for obtaining permission and proposals of its commercial operation implementation on real energy objects. comprehensive parametric identification of actual characteristic of the energy object will identify deviations in work of units or measuring devices at an early stage as well as track uncontrolled "ran out" parameters and optimize the timing and composition of the repair units with prevention of accidents with simultaneous provision of a high level effective and environmentally safe operation of EA equipment.

Key words: energy object, actual characteristics, quality performance, real state, operation reliability, state prediction.

ПІДВИЩЕННЯ ЕНЕРГОЕКОЛОГІЧНОЇ ЕФЕКТИВНОСТІ ТА НАДІЙНОСТІ ЕНЕРГЕТИЧНОГО ОБЛАДНАННЯ КОМПЛЕКСНИМ МОНІТОРИНГОМ ЙОГО ФАКТИЧНОГО СТАНУ

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Робота присвячена удосконаленню та підвищенню надійності та оперативності роботи методів оцінки умов експлуатації енергетичного обладнання за рахунок реалізації комплексної параметричної ідентифікації фактичних характеристик енергетичного об`єкту з метою підвищення рівня енерго-екологічної ефективності та надійності експлуатації агрегатів. Розроблено та впроваджено комплексну параметричну ідентифікацію фактичних характеристик енергетичного об`єкту: алгоритми, блок-схеми та методики визначення показників ефективної роботи енергетичного об`єкту на прикладі газоперекачувального агрегату та водогрійного котла, програмне забезпечення для автоматизованих систем контролю фактичних характеристик. Проведені реальні випробування комплексної параметричної ідентифікації фактичних характеристик з отриманням дозволу і пропозиції впровадження її у промислову експлуатацію на реальних енергетичних об`єктах. Розроблена комплексна параметрична ідентифікація дозволяє виявляти на ранньому етапі відхилення в роботі агрегатів чи вимірювальних приладів, відслідковувати неконтрольовані «вибіги» параметрів та здійснювати оптимізацію термінів і складу проведення ремонтів агрегатів із запобіганням аварійних ситуацій та прогнозування стану з одночасним забезпеченням високого рівня ефективної і екологічно безпечної експлуатації обладнання на енергетичному об`єкті.

Ключові слова: енергетичний об`єкт, фактичні характеристики, якісні показники, реальний стан, надійність експлуатації, прогнозування стану.

PROBLEM STATEMENT. Modern pace of scientific and technological progress as well as the need of energy resources and profitable production efficient usage requires prompt response to any changes in the real condition of equipment in order to improve the reliability and extend its lifetime.

Operational technical diagnostics of actual operating conditions of equipment, installations and thermal power objects of the undertaking various industries shall consider the actual values of parameters and characteristics. At the expense of units wearing and equipment parts changes in operating conditions, common technical and ecological characteristics of its work are constantly changing. In the majority of cases these changes are not reversed. Therefore there are possible situations when the total error of complex factors and variables that influence on the effectiveness and safety of equipment and installations may exceed allowable values, which can lead to unpredictable effects, adverse effects and emergency situations. For alignment of such situations it were developed methodological frameworks, algorithms and software and analytical complex (SAC), capable of quickly analyzing and fixing the time deviation values as well as the important parameters of real and nominal values, analyze their credibility and issue recommendations to address the causes to prevent negative consequences. The particular importance of this work is in the analysis of thermal power equipment working conditions where high-parametric composed and complex aerodynamic, thermal, mechanical and energy transforming processes, including gas pumping units (GPU), compressor stations and boiler units composed of combined heat and power boilers to districts. Development of the systematic methodology of identification of the energy facilities operation actual state is necessary and important for the fuel and energy complex, the reliability of which affects the state energy independence.

The work is devoted to analysis the features of developed complex parametric identification of actual characteristics (CPI AC) power equipment on specific objects to ensure systematic monitoring, analysis and forecasting of real state as separate assemblies, units, installations and objects in general. CPI AC energy object allows one making calculation of basic values and characteristics of the actual status and working conditions concerning reliability, efficiency and environmental equipment operation.

The aim of the work is to check the adequacy of the developed CPI AC through analyzing of its trials and comparing the thermo-technical data surveys with investigation test data using the CPI AC methodology.

EXPERIMENTAL PART AND RESULTS OBTAINED. Today, the question of determining the real effective performance in thermal power industry dedicated to several works [1,2]. In particular, the known fundamental work [3-4] devoted to energy saving techniques in the production and distribution of thermal energy. Algorithm of diagnosis and assessment of the GTU in [5] proposed to conduct several stages. The most complete, detailed and consistent diagnostic performance and functional characteristics of the technical state of GPA given in [6]. Analysis of existing methods for the energy object (EO) actual state characteristics determination is made in conducted research[7]: sources for the diagnosis and gas pumping aggregates (GPU) parameters monitoring in the energy items, the review of the literature with regard to reliability and diagnostic service facilities; a common approach to the development of control units means, programs to perform rapid diagnosis of the technical state of gas turbine units compressor plants of gas mains (GTU CPGM); the need to improve environmental safety of the GTS GM using modern approaches to developing models and methods for optimizing their work; strategy of a gradual decomposition GTS optimization of the system key equipment and components; temporary methods of some GPU calculating thermal parameters developed by SPC "TehdiACaz" DC"Ukrtransgaz" in the study of these methods is determined as their application contains the following deficiencies:

– limited range of measured instrument parameters;

– biggest value among actual error values determination and lack of parameters regular channels;

– complexity of mathematical description and impossibility of problem solution in actual analytical measurement processes occurring in the units;

– the lack of modern methodological basis in thermal and gas-dynamic testing with regard to the parameters and characteristics of actual values;

– lack of adequate assessments and neglecting of substantial complexity and interdependence of various factors, variables and parameters on actual data and operational characteristics of thermal technological equipment;

– lack of common approach to solution the problem of estimation of the actual technical condition of units and objects during their operation.

The work formed the general concept the of CPI units actual characteristics determination and the conditions of its use in the compressor plants (CP) operation in compliance with reliability and efficient operation with the ability to transition to the development of integrated approaches and universal implementation of all operating parameters of identification object.

CPI AC EO is created by new algorithm for consistent actions, the implementation of which requires systematization and analysis of complex characteristics and parameters. Whereas every object has a significant energy equipment list, the final result may be obtained only after the entire complex system analysis of different types of factors that directly or indirectly characterize magnitude and exploitation characteristics.

The proposed algorithm of the integrated parametric identification of GPU actual characteristics includes the following steps [7], disclosed in Fig. 1:

1) basic identification values which characterize GPU technical condition and efficiency;

2) determination of auxiliary variables and measuring objective as well as precise parameters and equipment performance;

3) development of mathematical connection that combines the main and auxiliary parameters;

4) parametric connections and comparisons systematic analysis of equipment nameplate actual state;

5) analysis and systematization of different factors which indirectly affect the equipment operation;

6) providing opinions operational personnel to the actual state of the unit on the basis of parameters operational identification and recommendations to reliable operation of the equipment.

Separate algorithms for determining considered key indicators of GPU effective elements on analytical expressions and dependencies using hierarchical decomposition into constituent units and basic units.

The methodology of CPI AC determined list of key indicators of the level of exploitation of the energy-environmental state object. For this purpose, any energy object undergoes decomposition into components and basic components, considered separately algorithm for determining key indicators of effective work of each of the items on analytical expressions and dependency.

For example, by looking at the object as an energy gas pumping units composed of compressor station (CS) decomposition is as follows: gas turbine, centrifugal supercharger and regenerator. Gas turbine consists of axial-flow compressor, combustor, gas turbine, which in turn consists of low-pressure turbines and high-pressure turbine.

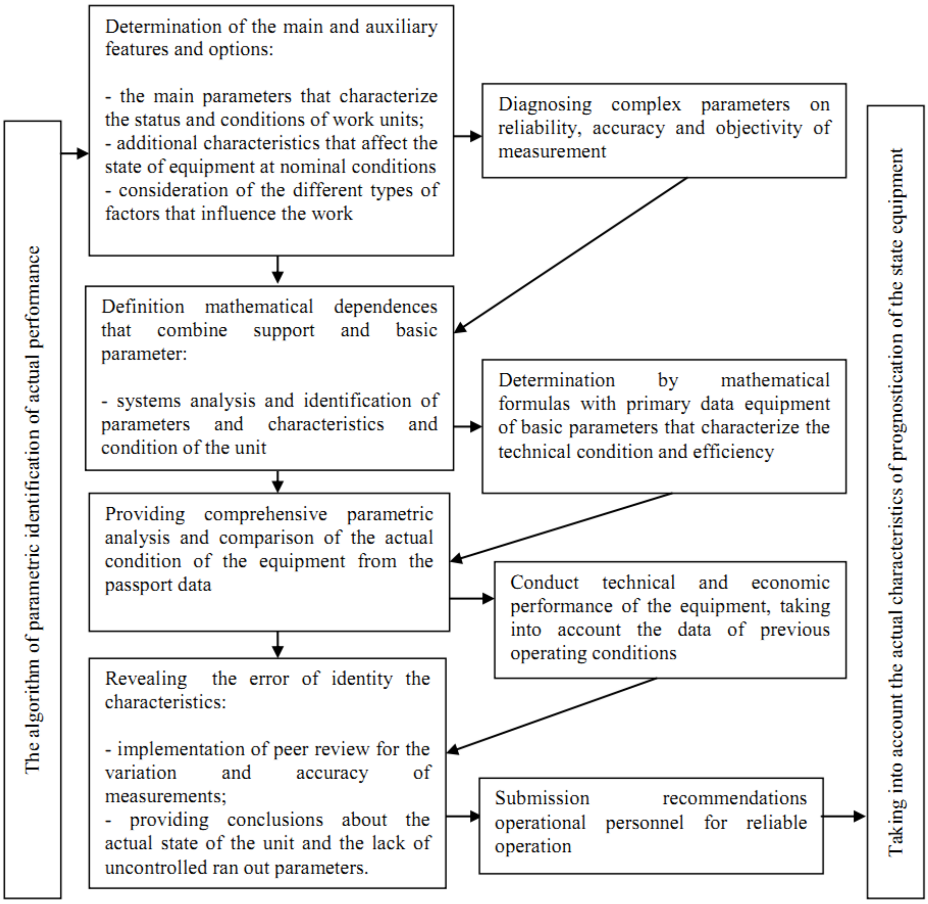

Figure 1 – Algorithm for determining the energy facilities actual characteristics

So, for the implementation of the algorithm separately created a flowchart of identifiers identifying key elements of each of the eight compressor units, which is determined by the level of reliability and performance of GPU elements.

The general scheme of analytical units main parameters that characterize the state of operation of the main parts of GPU and generally developed with separation of key performance indicators and reliable approach each element. Such approach is the basis of complex parametric identification of the actual characteristics of the object in real time with the definition of the following basic and auxiliary parameters [9]:

– reduced natural gas consumption;
– power GPU;
– coefficient of performance (COP) gas turbines;
– the efficiency of the supercharger;
– reduced speed supercharger turbine shaft;
– reduced speed shaft turbine high pressure;
– displaying the maximum temperature at the outlet of the power turbine or exhaust GPU before regenerator.

Further, the values of the main and auxiliary variables and parameters measured with devices, sensors and the basic quantities characterizing the technical condition and efficiency of the GTU are calculated. After this a comprehensive parametric analysis and comparison of the actual equipment condition with rated and archive data is fulfilled. Each of the first basic parameter is compared with rated value, optimal and archival values, and in mismatch condition of any parameter the values of the quantities correspondence, measured with devices and entered into the expression of this parameter are verified [8].

Also, at this stage, there is the identity of the error detection characteristics.

At the final stage the steps are taken to obtain a result which allows one to determine the actual performance, analyze operating performance and provide operational staff recommendations for reliable equipment operation.

After the testing CPI AC algorithm, taking GTU as an example, it turned out that controlled devices and sensor parameters are not fully make it possible to achieve the desired result. Therefore it was proposed to carry out more in-depth parameters analysis of feedback implementation and checking the performance authenticity.

First there was a proposition to solve the problem of AC GTU determination by additional comprehensive inspection of the input data, measured with all GTU instruments and influence directly and indirectly, to determine all the parameters that characterize effective GTU work and COP in a whole [10].

With this view, the actual characteristics identification of the GTU equipment was offered to perform by checking the authenticity of the input variables with regard to accuracy class measuring device and additionally with mathematically calculate their values consecutively on the basis of formulas and equations. The results of the two checks were compared considering the adequacy of real values and acceptable error.

Comprehensive parametric identification of the EO actual state is performed by implementing the following:

1) sampling parameter values from an existing automated control system (ACS) as variables measured with appliances;

2) test input:

2.1) test parameters for reliability with regard to accuracy class measuring device;

2.2) analytical test of parameters values for plausibility (solving the inverse problem of determination of the relevant variables or parameters values on the basis of formulas and other parameters that make up this formula);

3) comparison of the parameters values stated in para.2.1 and 2.2 with regard to permissible error of measurement devices;

4) collecting and archiving information with plotting in real-time dependency input data received from the devices and determined mathematical analysis of operating time in this mode;

5) operational staff providing opinions about the comprehensive parametric identification quality of the actually identifiable GTU characteristics;

6) base and content archiving of the actual operation quantities.

Thus, the parametric identification methodology of the actual GTU characteristics involves seven basic quantities characterizing the GTU technical condition and efficiency. Checking the input data, measured using devices is controlled by analytic dependencies.

Therefore, the given parametric identification methodology of the actual gas compressor units characteristics can detect early abnormalities in the unit work or measuring device, allows one implementation of timely repair units and aggregates and timely notify the uncontrollable modes and emergency situations [11].

For a real implementation of the CPI AC methodology the software system (SS) based on parameters control of separate equipment and GTU in a whole, implemented at "Berdichev" was created.

The work on the basis of the developed CPI AC GTU makes it possible to create information-methodological basis of the new generation of software system for adequate identification of actual performance (SS IAP) GTU.

This software system (SS) of new generation was implemented by the following sequence:

1) selected unit for implementation: Compressor Station "Berdichev" of gas turbine drives blowers;

2) determined the main characteristics of the equipment type gas compressor units GTK-10;

3) analyzed the existing GTU control system with 684 monitoring parameters which is the basis for monitoring the process and the calculation of technical and economic parameters of operation GTU and CPI AC in general;

4) carried out the analysis of technological indicators and noted main work features in the GTU terms of security;

5) analyzed the environmental performance, which should indicate the quality of energy and GTU ecology operation;

6) the SS of the actual GTU characteristics identification, which is based on patented CPI AC methodology;

7) tested the SSCPI AC GTU in actual practice;

8) developed the necessary supporting SS documentation;

9) analyzed the test results and signed implementation acts.

On the basis of real tests it was proved the feasibility of CPI AC GTU creation, which provides conditions for implementation of integrated and systematic analysis of the actual state of individual units of GTU and the GTS in general, and monitoring parameters of the GTU in real time allows one to calculate basic values of its operation and characteristics concerning reliability, economy, environmental friendliness of equipment and predict its working lifetime.

Software system of the GTU actual performance identification in real conditions fulfills the following functions:

– information processing from primary sensors and transducers work processing GTU equipment in real time on a given discrete list of parameters (database);

– automatic database maintenance information technology with its subsequent restoration in real time every 2 ... 15 seconds (there is a possibility to regulate time);

– data analysis of primary converters to meet their real state regime unit;

– determination of the level of parameters identification reliability in the real state of the operation unit;

– check for uncontrolled variations of parameters within the maximum permissible values;

– fixation and signaling the beginning and ending of the fugitive ran parameters and their values;

– issuing recommendations personnel in case of approaching parameter values to critical values;

– display the current status of the process for videograms;

– print a shift report;

– reconsideration of the history process in tabular and graphical form.

Software system CPI ACGTU is the basis for creating a new generation of automated mechanism that allows one a continuous mode of monitoring any and all technical parameters of gas compressor units and compressor station in general and allows one optimization of technological processes lengthening and general overhaul of moto equipment, increasing level of energy saving of logistical and fuel and energy resources.

To test the adequacy of the software system CPI ACGTU and methodology in general it was done examination analysis comparing survey data heating unit type GTK-10 at COP "Berdichev" with real data test unit in identical initial and boundary conditions that were laid in the software package. For this case, the software system CPI AC was connected to the existing GTU parameters monitoring system with no possible impact on the performance of standard sensors and devices that are fully guaranteed no influence of CPI AC software system on real values and unit operating parameters.

During the actual GTU test of GTK-10 type st. №1 CS "Berdichev" "Kievtransgaz" at three modes of measurement parameters were carried out in regular full-time points using techniques and instrumentation. The value of the three major indexes to their further dependencies are shown in table 1, and appropriate dependences with drawing values of variables from regular system monitoring unit and a new software system using CPI AC are shown in Fig. 2, 3.

Table 1 – Indicators and values GTU GTK-10 during the test CPI AC system

Modes of regular monitoring system and using the CPI AH methodology		Effective GTU coefficient of efficiency, η_e	Reduced effective power, $N_{ГПА}$, kW	Reduced fuel gas consumption, $G_{пгпр}$, nm^3/h
1 mode	The value of regular system	0.309	8214	2774
	Indicators using the CPI AH	0.311	8220	2773
	Fault +/-3 %	0.320/0.301	8466.6/7973.4	2856.19/2689.81
	Fault+/-1 %	31.411/30.789	8302.2/8137.8	2800.73/2745.27
2 mode	The value of regular system	0.313	8758	2918
	Indicators using the CPI AH	0.310	8740	2917
	Fault+/-3 %	0.3193/0.3007	9002.2/8477.8	3004.51/2829.49
	Fault+/-1 %	0.3131/0.3069	8827.4/8652.6	2946.17/2887.83
3 mode	The value of regular system	0.320	9335	3038
	Indicators using the CPI AH	0.309	9310	3040
	Fault+/-3 %	0.31827/0.29973	9589.3/9030.7	3131.2/2948.8
	Fault+/-1 %	0.31209/0.30591	9403.1/9216.9	3070.4/3009.6

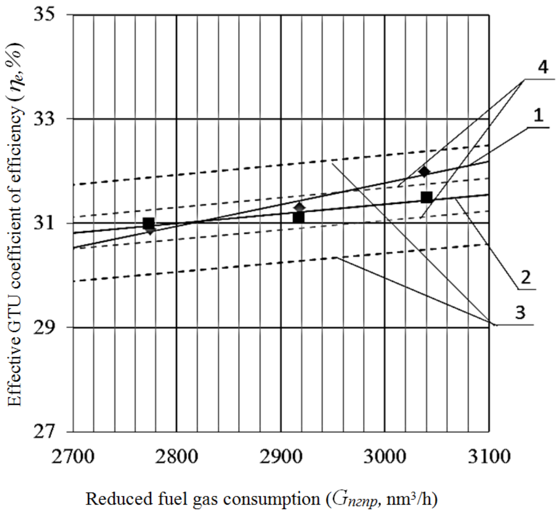

Figure 2 – Dependence of effective GTU coefficient of efficiency on reduced fuel gas consumption:
1 – trend line of thermos-technical surveys data by standard sensors, devices using native methods of the processing results;
2 – trend line investigation test data using the CPI AC GTU methodology;
3 – dotted line that corresponds to the fault level ±3 %;
4 – dotted line that corresponds to the fault level ±1 %;
◆ – thermo-technical surveys data of the unit type GTK-10-4 with standard devices on existing methods;
■ – GTU investigation test data using the CPI AC methodology

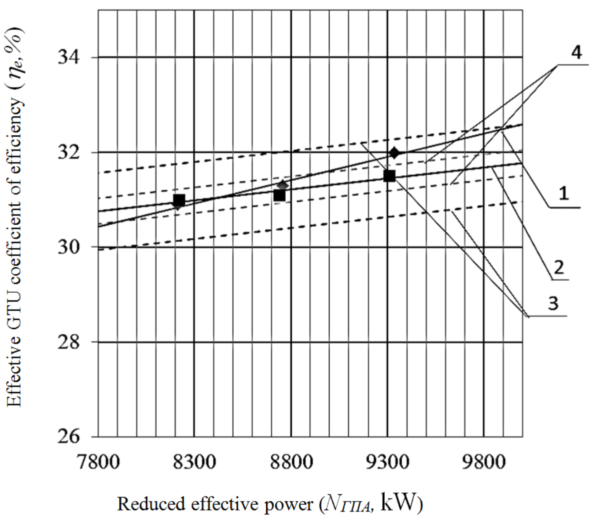

Figure 3 – Dependence of effective efficiency coefficient of reduced effective power of GTU

In a line 1 for data dependences (Fig. 2, 3) there are values that were calculated under existing organization methods and processed by least squares based on the values of parameters measured by sensors staff or equipment. Line 2 displays the data recorded by system program with regard to the CPI AC methodology and treated with similarly methods.

Since the regular system of measurement has allowed error of parameter values and the values of up to 3 %, the graphs plotted with dotted lines, 3 parallel lines, 2 at a distance of + 3 % and –3 %, shows possible deviations of parameter values or calculated values of permissible error sectors.

For example, at the dependency graph of effective GTU coefficient of efficiency from reduced fuel gas consumption (Fig. 2) all observational data during the pilot tests are within the permit error of 3 %.

Software system that implements CPI AC methodology, allows one to change the size of error for each parameter or set the value and importance of the operator under the option. In these pilots testing the CPI AC software system error was set at 1 % for all parameters and variables. Dotted lines corresponding to possible changes of parameters and sizes in the range of 1 % (4) plotted along the lines of the data according to the CPI AC methodology.

Thus, the graphs applied parallel dotted lines that allows one to perform evaluation upon regular forms of control monitoring system parameters with the value of 3 % (dotted line 3) and parallel dotted lines, to determine the parameters and values to within 1 % (dotted line 4) according to the CPI AC methodology (Fig.2, 3).

The graph shows that the data obtained by standard surveys of thermal sensors, devices using native methods of results and test data processing using the methodology of the CPI AC GTU are within error of size not exceeding 1.3 %.

Along with this, the graphs have obvious differences in the trends of (slope of the trend line to the axle axis) parameters and values change which make analyze the results more thoroughly.

Trend lines of thermos-technical surveys data by standard sensors, devices using native methods of the processing results have the form of stable characteristics that meet passport (regular) dependence. This confirms the falsity of existing methods for use in exploitation conditions and processing the results of thermos-technical tests of units after repairs, which are in long-term operation. Permanent (adopted by the organization) method does not take into account for quality changes in state assemblies and parts of the unit and calculates technical and economic dimensions and characteristics with the assumption that they are stable since the start of the unit work.

So, according to this approach it is believed that after the planned capital repairs and assemblies, complex parts, parts of the unit and its properties and characteristics are restored to the rated (original or ideal) values. This approach eventually make it impossible to identify at an early stage deviation from the actual parameters and operating conditions of the unit and can lead to sudden node failure, individual parts of the unit and the emergency stop, which may adversely affect the term of the working life and energy efficiency of ecological gas compressor units.

CPI AC methodology allows performing parametric variables and parameters accurate identification using feedback and uses for the analysis and prediction of the actual unit characteristics operated for a long time (more than 100 thousand hours) underload conditions.

This means that the CPI AC methodology provides a realistic assessment of the main unit characteristics. In addition, the accumulation of data for two or three years of GTU operation (more than 100 thousand hours) allows during the application of the CPI AC methodology not only more accurately determination of the actual operating unit characteristics, but also to predict the future behavior of the GTU, to optimize the timing of planned capital repairs and to determine the quality of these repairs.

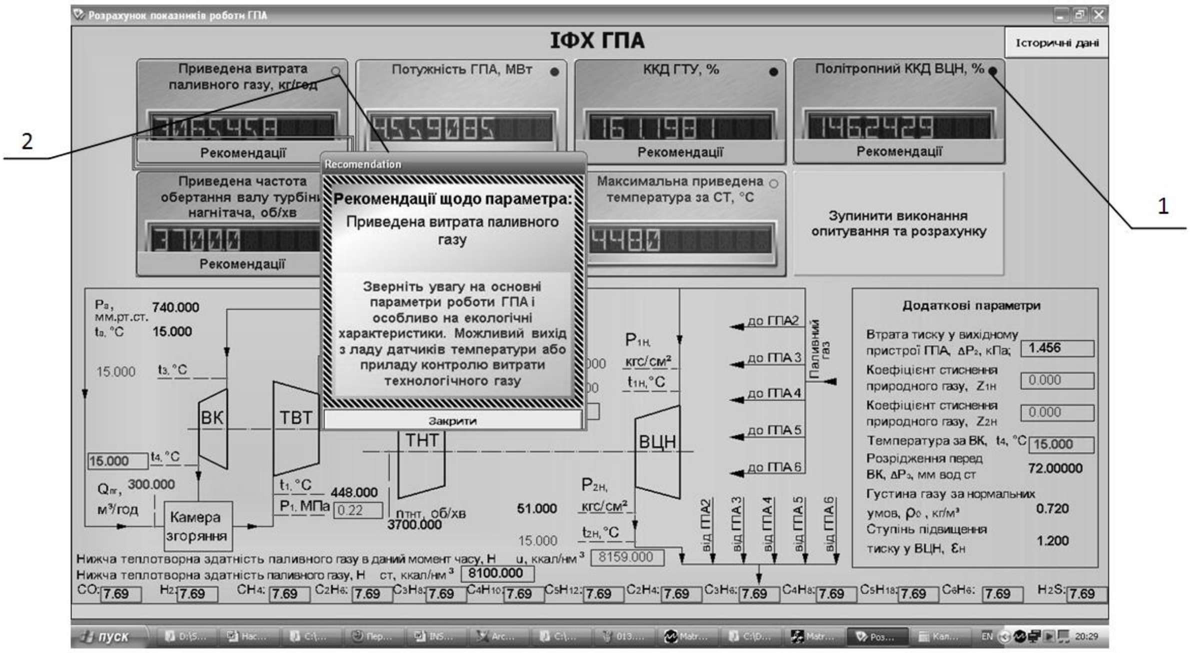

Figure 4 – Main window. Calculation

Figure 4 shows the SS CPI AC GTU interface under its operation. The program provides notification of the successful reading of necessary parameters procedure, which appears with the help of indicators on the top right box of technical and economic markers in the main window (Fig. 4) which shows: alert indicator (green light) on successful reading needed to calculate this value set parameters and its actual value within the established error (1) and the indicator notify (red light) on errors, damage or devices (2).

After performing operations the indicators change color to black, indicating the readiness of the program to the next request and payment.

Data collection and calculation of key performance parameters occurs automatically with regularity once every 2 seconds.

Thus, it is verified the input data correspondence (values measured with instruments) to the established limits and passport data.

Getting recommendations for reliable operation is performed with pressing the "Recommendations" button which is opposite to the appropriate parameter (Fig. 4).

Analysis the chronology in graphs in the system and history and value results, changes and errors of measurement values and fundamental parameters (Fig. 5) are provided by accumulating and archiving data sets.

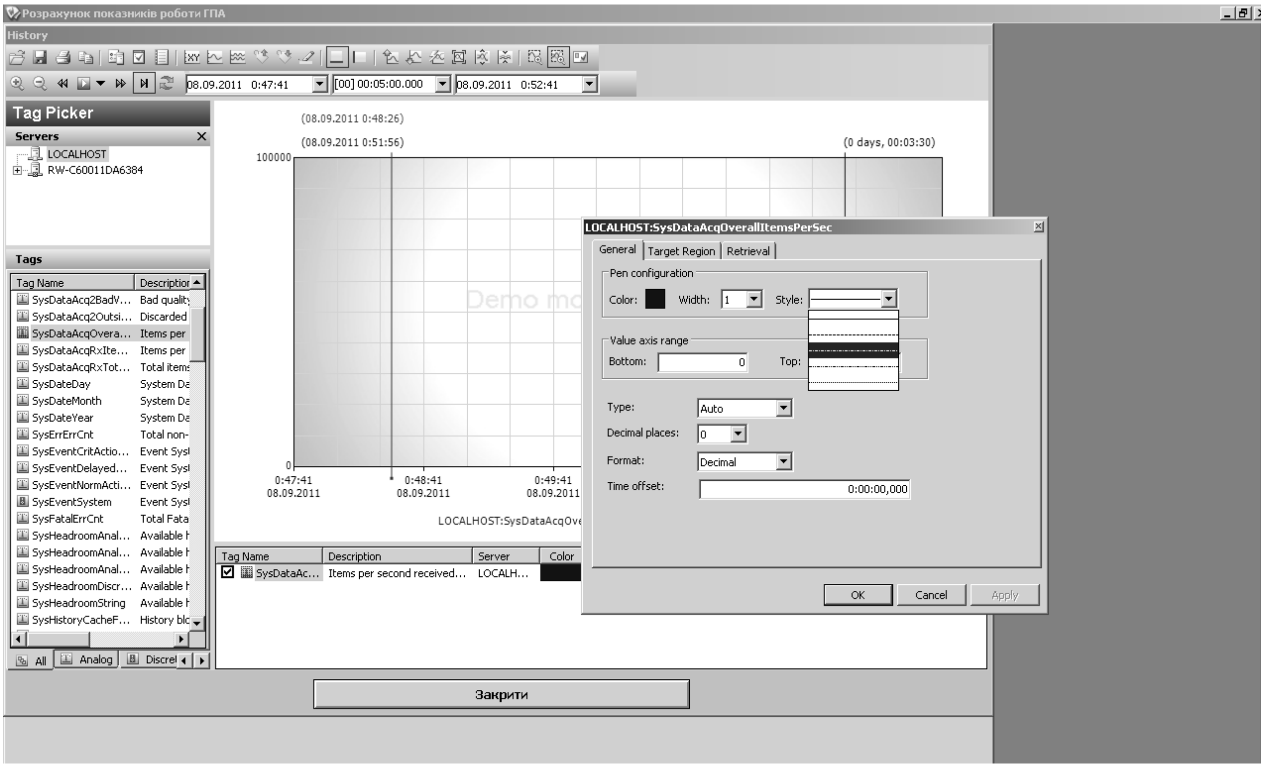

Figure 5 – Window view archived data

According to SS CPI ACGTU test results of type GTK-10 the responsible persons of gas transmittal pipelines administration "Kievtransgaz" and SOE "Ukrtransgaz" were given suggestions on the feasibility of its implementation in operation at compressor stations of National Joint Stock Company "Naftogaz of Ukraine" and signed the implementation act.

Similar CPI AC software systems were developed for hot water boilers type KVHM-20 and PTVM-180 which are implemented on real objects, signed the relevant acts.

CONCLUSIONS. It was conducted the research on the methodological foundations for creation and practical implementation of the comprehensive parametric identification of actual energy performance object to determine the actual parameters, variables and criteria for evaluation of energy efficiency and aggregates environmental reliability. If the existing standard system of the units' parameters monitoring connect with SS CPI AC, it will detect early abnormalities in work of units or measuring devices, monitor uncontrollable "ran out" options. Transition to a comprehensive analysis creates conditions for the timing of aggregates repair, prevention of accidents while ensuring a high level of equipment efficient operation and continuing of working moto installations.

It was developed the universal methodology to determine the actual performance units which offers the opportunity to implement automated load control equipment in best performance and efficient operation of facilities for different modes of load in real time.

Its implementation on the EO allows significantly increase the reliability and profitability of both individual units and the object in general, reduce costs for units support in good operating condition through the use of predictive and real objective information, generate optimized repair plans and renovation of equipment, optimize processes and increase the reliability and working life of the EO in a whole.

The main conclusions of this research are the following:

1. It was developed the methodology of the comprehensive parametric identification of actual energy performance of object which allows one in real-time to identify the actual operation characteristics with high precision and the ability to predict their performance operational and technological value in the near future.

2. It was proved the CPI AC efficiency and advantages in terms of existing standard control systems of the equipment operational characteristics handling.

3. Comprehensive testing and experience of the developed SS CPI AC on real objects proved the possibility for more accurately determination of the auxiliary and main equipment actual parameters during operation and predict the nature of the qualitative change in the future.

4. Universality of the CPI AC methodology for different types of objects brought by the examples of GTU and the boiler with the development and implementation of new algorithms and EO flowcharts installations.

5. Comprehensive testing methodologies of actual performance comprehensive parametric identification were conducted in real conditions at the operating units to obtain authorization and implementation of its operation proposals, which composed the appropriate acts.

6. There were developed algorithm and methodology for a new type of automated monitoring, analysis and recommendation providing to the operational staff during the implementation on real objects allow achieving high levels of efficient, reliable, economic and environmentally safe operation of the equipment and the object in general.

Thus, the developed CPI AC methodology creates conditions to improve the equipment quality and reliability, complex monitoring of a vast amount of parameters and technical and environmental performance, analysis of the real state and optimization of inter-maintenance periods, moto objects power extension and lays the foundation for the transition to a new the level of energy efficiency in energy management objects.

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ПОВЫШЕНИЕ ЭНЕРГОЭКОЛОГИЧЕСКОЙ ЭФФЕКТИВНОСТИ И НАДЕЖНОСТИ ЭНЕРГЕТИЧЕСКОГО ОБОРУДОВАНИЯ КОМПЛЕКСНЫМ МОНИТОРИНГОМ ЕГО ФАКТИЧЕСКОГО СОСТОЯНИЯ

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Работа посвящена совершенствованию и повышению надёжности и оперативности работы методов оценки условий эксплуатации энергетического оборудования за счет реализации комплексной параметрической идентификации фактических характеристик энергетического объекта с целью повышения уровня энергоэкологической эффективности и надёжности эксплуатации агрегатов. Разработана и внедрена комплексная параметрическая идентификация фактических характеристик энергетического объекта: алгоритмы, блок-схемы и методики определения показателей эффективной работы энергетического объекта на примере газоперекачивающего агрегата и водогрейного котла, программное обеспечение для автоматизированных систем контроля фактических характеристик. Проведены реальные испытания комплексной параметрической идентификации фактических характеристик с получением разрешения и предложения внедрение ее в промышленную эксплуатацию на реальных энергетических объектах. Разработанная комплексная параметрическая идентификация позволяет выявлять на раннем этапе отклонения в работе агрегатов или измерительных приборов, отслеживать неконтролируемые «выбеги» параметров и осуществлять оптимизацию сроков и состав проведения ремонтов агрегатов с предотвращением аварийных ситуаций и прогнозирования состояния с одновременным обеспечением высокого уровня эффективной и экологически безопасной эксплуатации оборудования на энергетическом объекте.

Ключевые слова: энергетический объект, фактические характеристики, качественные показатели, реальное состояние, надежность эксплуатации, прогнозирование состояния.

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