PRIMENA SOFTVERSKOG SISTEMA ZA DIJAGNOSTIKU RADA PARNOG BLOKA TERMOELEKTRANE

APPLICATION OF THE SOFTWARE SYSTEM FOR OPERATION DIAGNOSIS OF A STEAM POWER UNIT

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Abstract: Despite the long operating experience with the steam power units in Serbian power system (some of them are at the end or even passed their planned working lives), unfortunately there is a lack of data for their operating regimes, the process parameters and the performance deviations, the economy and operating states for the previous period. These data would not only be useful for the optimal process control but also for the planning of maintenance and service agreements, retrofits and repowering of power plants. For these reasons and the others, also important, the software system for the diagnosis of operating conditions, control of economy and operating states of different components is being developed for the referential steam power unit. A better control of the process and operating state, thanks to the use of the results obtained with this software system, will bring lasting benefit to the efficiency and economy increase. Furthermore, it enables an increase of reliability and availability of steam turbine units and makes their working life longer.

Key words: Steam Turbine Unit, Software, Diagnosis, Performances, Economy

1. INTRODUCTION

For better understanding and control of processes in steam thermal power plants there is an increasing need for the additional analysis of processes. The diagnosis of operating conditions, control of economy and operating state of different components are the most important tasks in additional analysis of processes. To resolve these tasks, a software system for diagnosis of operation, control of economy and operating state of different components of steam turbine unit is being developed. The work on this subject had started much earlier, but in the conditions of very limited resources which did not enable the development of the software system like this [1,2].

The development of software system in question was followed by different objective and subjective difficulties. The complex structure of steam turbine unit and the large number of involved process parameters (over one hundred for the needs of software system) with their very fluctuating values, in certain measure unpredictable, has made this work much more difficult. Possible unavailability or inaccuracy of few values of process parameters in certain periods, which could endanger software system reliability and predictivity, is also an expected condition. Unfortunately, the deficiency in a small number, but necessary measurements, has additionally complicated the development of this software system. Certainly, noted difficulties were only the part of the problems we met with in the software development in progress. Also, the completely different software programming logic from classical programming one had to be developed. In the course of the software system development, the corresponding efficiency and functional organization of software system in detail had to be built to reach the target.

Software organization is based on functional modular principle which enables the exactly determined functions of different software units. We differentiate three basic groups of software modules: block for getting the referent data base for the need of software system, block of main software modules for different operative methodical functions for process analysis and block of the user communication software modules.

First operative software module is for getting the referent data base for the need of software system from the original source data bases of supervision acquisition system [3].

A group of main software modules of second block has the most important role and enables a complex process analysis.

Software module for "identification of steady regime" loads enables "recognizing" of steady regime loads on the basis of specifically built software logic and set input criteria (limited load gradient, maximal load deviation, minimal duration of steady regime) and calculates the mean values of processed parameters from referent data base for "identified" steady loads for the need of the next analysis.

Software module for filtering previously obtained values of parameters is the most important and a complex one. It calls the corresponding specialized software modules for multicriteria checking of particular processed parameters. If some of the processed values are not regular or available it would be substituted with the corresponding expected one for the referent load, according to the previous operating experience. Beside this role, these specialized software modules also serve for the calculations of different deficiency parameters and performances. Some of them have to be calculated in iterative procedures which involve the corresponding group of software modules.

The calculation of flow characteristic constant of steam turbine parts ("the flow cone consumption") [4], performed with software modules for particular turbine parts, is important for the control of operative turbine state.

The calculation of the process parameter and performance deviations and their influences on economy the other group of next software modules makes possible.

Current trend calculations of different process parameters and performances for referential level loads, which give information about current time-course of their values in operating conditions, are performed by specialized software module. These values are very important not only for following unit operation and its operating state, but also for checking the validity of processed parameters (software module for filtering). Following operating conditions and performances by current trends give the important characteristic of adaptivity to the software system.

Statistical analysis of the frequency for referential level loads and basic performances for longer operating period performs the particular software module.

The expansion line of steam in turbine can be obtained for the chosen identified load thanks to, for this purpose, specialized software module.

Beside noted software modules, some software components of "general" determination have been built in the software system, like, the software module for the calculations of thermodynamic characteristics of working fluid, and so on.

Preliminary testing of this software system has been made in the course of their development with the archived source data bases from previous period of operation for the referent unit. Also, the complete developed software system has successfully been tested on monthly sample of original data bases produced by supervision acquisition system. Expressed dynamic of load changes for the referent month render more serious the conditions for the software reliability. In the meantime the existing main acquisition software in the scope of supervision acquisition system has been changed with the new one giving in the other way formatted data. So, this software system, which has been installed in interval, could not operate with the new source data bases produced by the new installed software acquisition system except with those ones previously archived by the old software acquisition system. To overcome this difficulty we planned for the next phase in the near future to take data directly from SQL server. At the same time, the referent data base should be completed and software system upgraded and adapted with previously mentioned deficiency measurements which had to be installed.

The results obtained with this software system and presented in this paper are fully reliable since they have been realized with the original source data bases produced by previously installed acquisition system and so they are valid for previously noted period of steam turbine unit operation. Some of the results on development of our software system have been presented periodically. In the paper [5], along with the previously planned organization of software system, some results of preliminary analysis of steam turbine unit performances related to the development of the group of main software modules for different operative methodological functions for process analysis are presented. These results relate to the control of the influences of deviation of different process parameters and performances on heat rate, definition of the general operative condenser characteristic, determination of the flow characteristic constant of steam turbine parts from obtained schemes for different regime loads, and so on. In the second paper [6], beside some new experience in software system development, some results of preliminary testing of software system are also presented.

It should be noted that the development of this software system has been enabled thanks to the project participated by the Minister for the science of Republic of Serbia [7].

2. PRESENTATION OF RESULTS

Basic diagram of power generator changes with "identified" steady regime loads is presented in Fig. 1. Software module for "identification" of steady regime loads gives very satisfying results which are very important for getting the valid mean values of different parameters necessary for good process analysis for "identified" steady regime loads.

One of the input parameters which can be controlled is the fresh steam pressure. Their changes together with their calculated mean values for identified steady regime loads are presented in fig. 2.

Organization of getting the results has been planned after the user interface in visual software environment (third block of software modules) - fig. 3. The basic level gives the next possibilities for the chosen date: basic load diagram (active or reactive load), category of state definition for different points within a power unit (the order of the points follows the main stream of working fluid), category for the performances and category for the economy. In the scope of each category it is possible to choose on request the corresponding group, and in the scope of group it is possible to choose an option for getting a referent result in graphical form –fig. 4.

The other form of diagram which can be obtained relates to the calculated deficiency parameters or performances values of which are presented after bars for identified regime loads. Certainly, one of the most important performances of steam turbine unit is the efficiency of steam turbine unit, which can be now followed continuously for the first time thanks to this software system – fig. 5.

Statistical calculated results of steam turbine efficiency for the referent level loads and for the all identified loads for the referent month are presented in fig. 6. In general, the efficiency rises with load increasing. Total mean value for all identified loads is 41.3%. But, these values are smaller for about 5% in relation to data of the supplier.

Control of load by sliding pressure has been realized after characteristic (obtained by linear regression analysis) with the lower slope – fig. 7 in relation to those given by data supplier. It cuts the referent supplier characteristic at approximately 270 MW, so in the most circumstances of identified steady regime loads the realized values of fresh steam pressure have been lower.

Reheat steam temperature at input of intermediate turbine is also one of the parameters which can be controlled. In all identified regime loads for the referent month the values of reheat steam temperature have been below the predicted ones and statistically performed results for this temperature are given in fig. 8. Mean deviation of reheat steam temperature for all identified regime loads was -17.3^{o}C.

The influences of the particular parameter or performance deviations on heat rate deviations reflect on economy of steam block. These deviations of heat rate can also be expressed after loss of power loads. Mean values of loss of power loads influenced by fresh steam pressure and reheat steam temperature deviations for referent load levels are presented in fig. 9. Also, total mean values of loss of power loads are given in figure (-1.315 MW for fresh steam deviations and -1.71 MW for reheat steam temperature deviations).

Control of stream flow state of turbine can be followed by the calculations of flow characteristic constants of turbine parts ("cone consumption") for identified operating steady regime loads. Unfortunately, we have no information that it was done in this form in operating conditions anywhere. The results of the calculations of the flow characteristic constants for high pressure turbine have been given in fig. 10. There are two characteristics given: the characteristic with lower values respond to the flow characteristic constant for the points input-output of high pressure turbine and second characteristic with higher values respond to the stream flow turbine part from the point at output of first action (impulse) stage to the output of high pressure turbine. For the second characteristic which relates to the turbine stages (cascades) of the same type it can be said that it is more relevant and shows the better properties: the value is nearly constant for all the range of loads with perhaps expected only slightly higher value at lower loads. Because there is no information from the supplier data for steam pressure behind the action stage, the obtained values for the second characteristic cannot be discussed in relation to the starting design state. However, for the first characteristic, the obtained mean value for the flow characteristic constant is approximately the same to that one for the rated load which is 0.009 m^2, or exactly it is only something higher (0.00917 m^2), which corresponds probably only to some extent aggravated operating state of high pressure steam turbine.

According to the great importance of current trends of different parameters and performances in following of process realization and operating states of different parts, the results of current trend calculations for fresh steam temperature for referent level load 310 MW are presented in fig. 11 for cumulative duration of last one hundred hours.

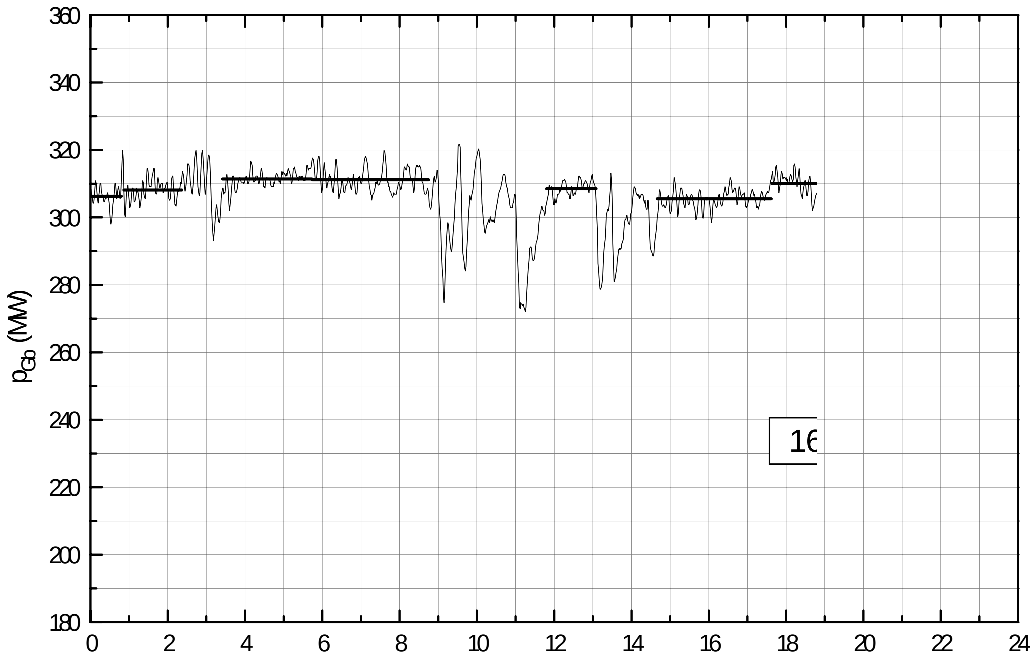

Fig. 1. "Identified" steady regime loads for the referent day

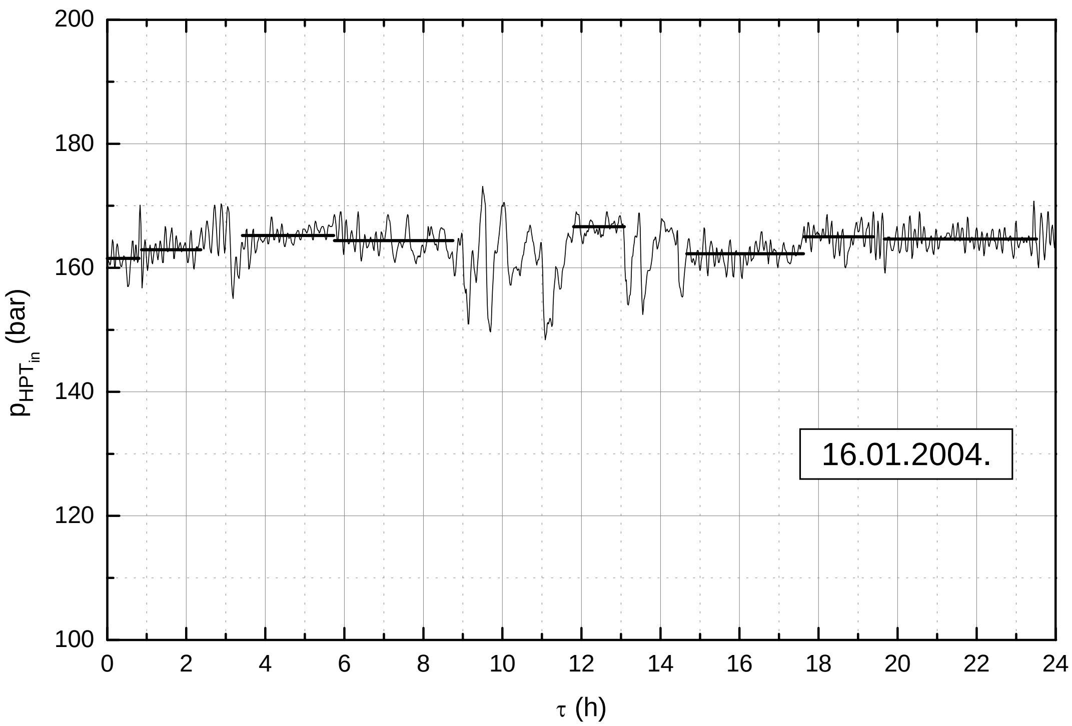

Fig. 2. Fresh steam pressure changes and its mean values

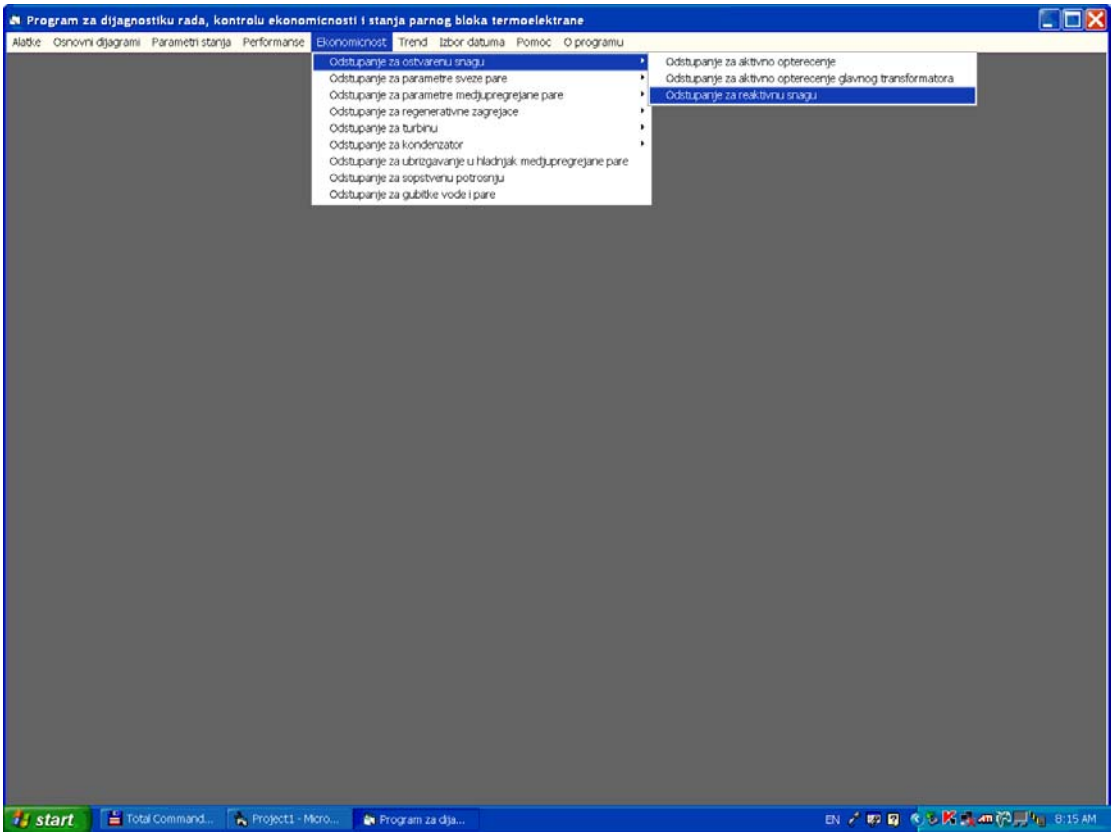

Fig. 3. Appearance of basic window with menu options

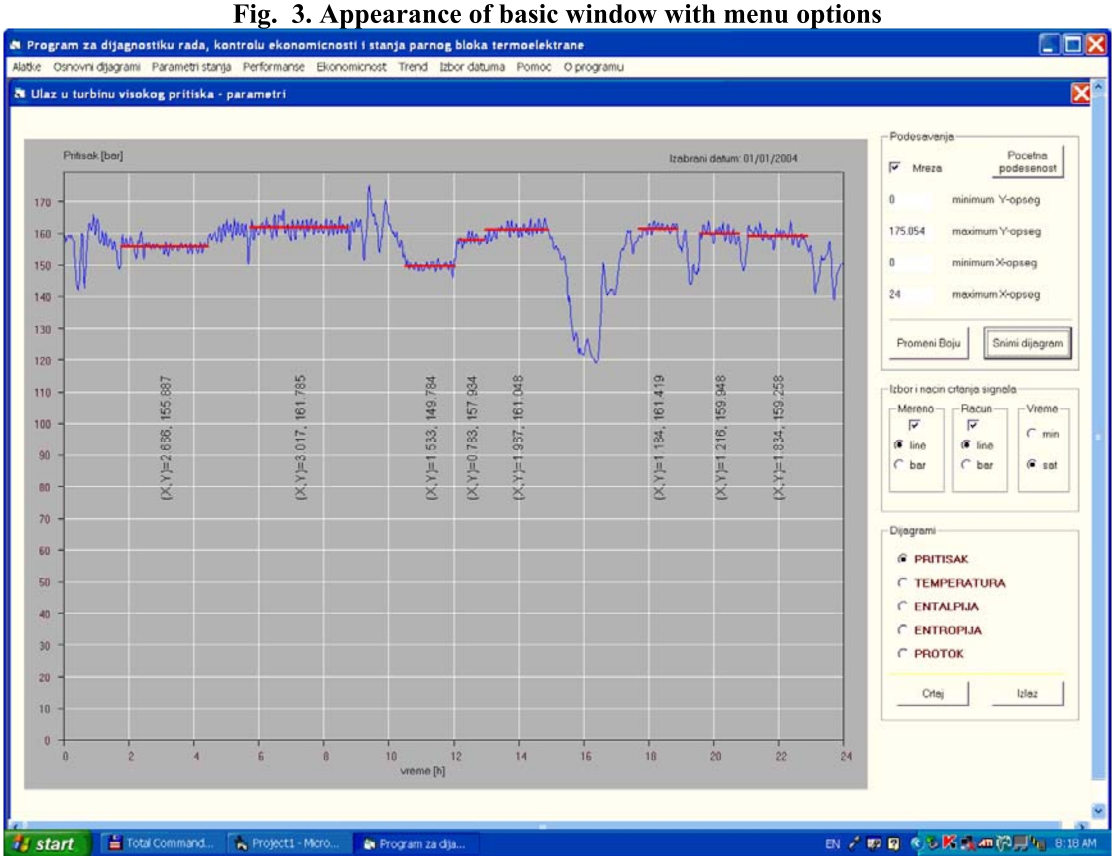

Fig. 4. Appearance of diagram for fresh steam pressure changes

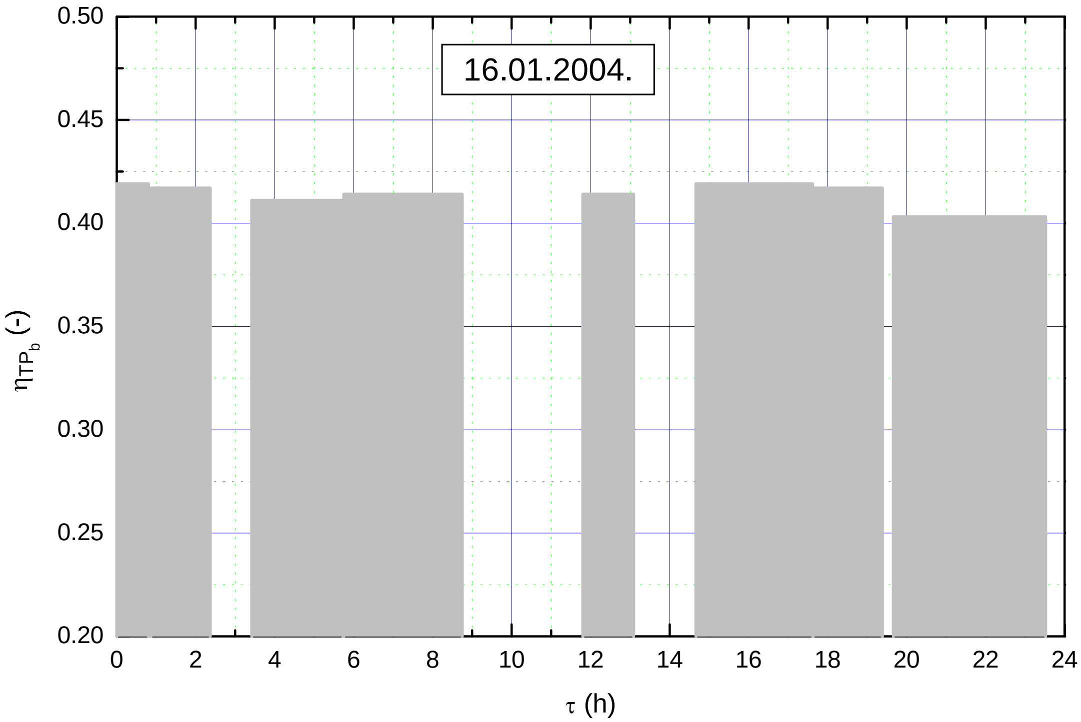

Fig. 5. Efficiency of steam turbine unit for "identified" steady loads

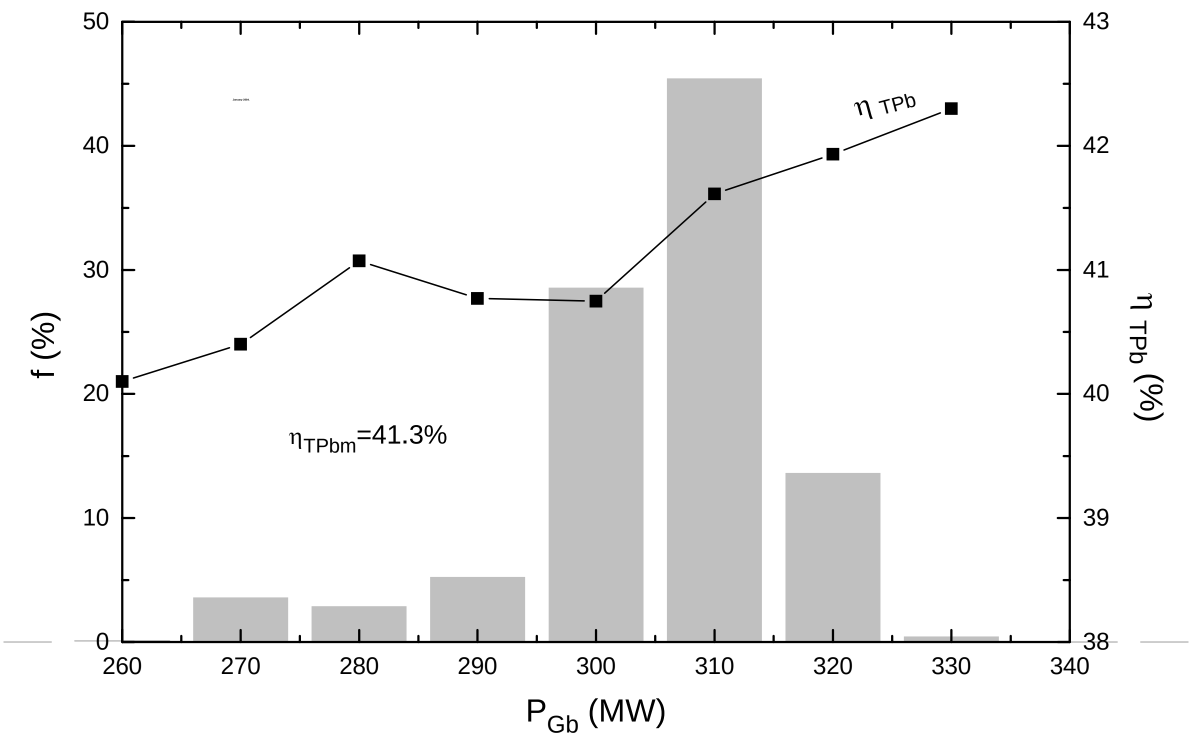

Fig. 6. Statistical results for the efficiency of steam turbine unit

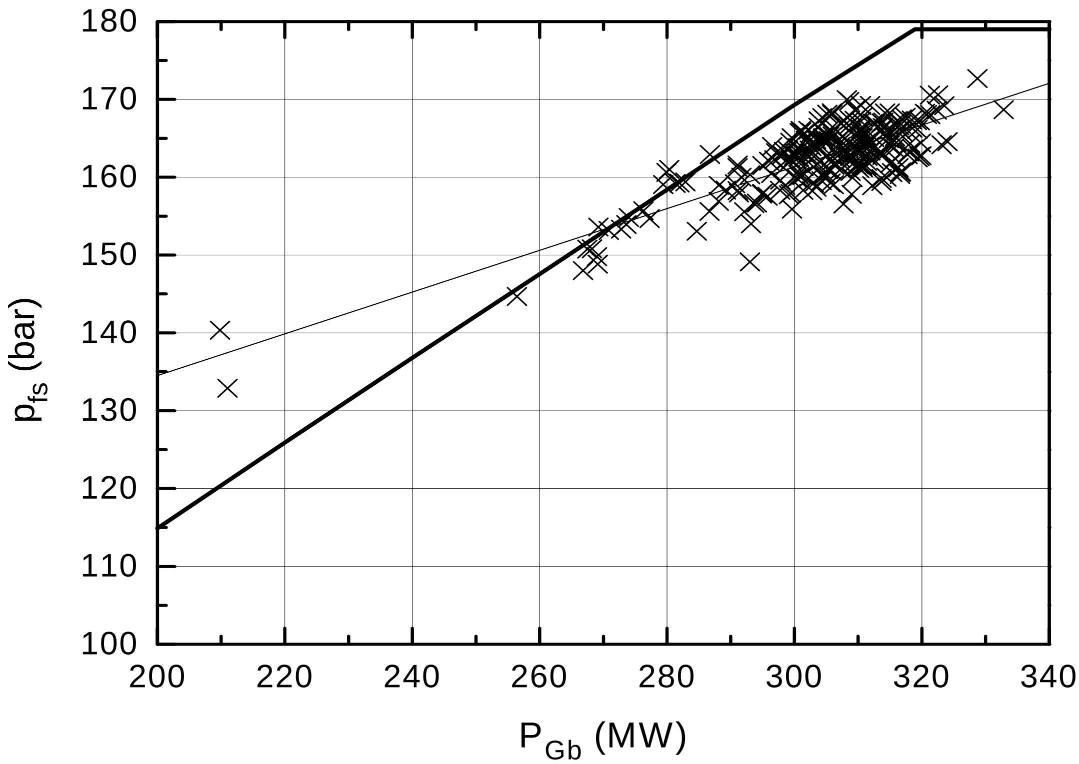

Fig. 7. Fresh steam pressure values for steady loads in relation to design characteristic

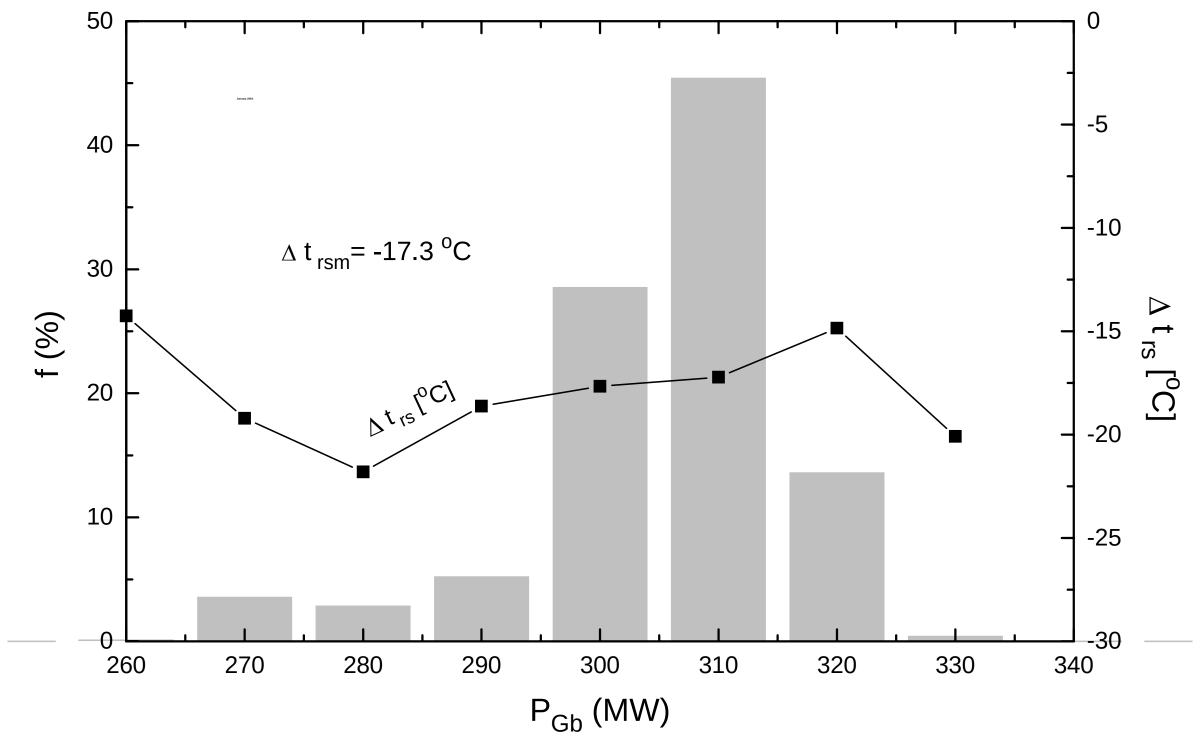

Fig. 8. Statistical results for reheat steam temperature deviations

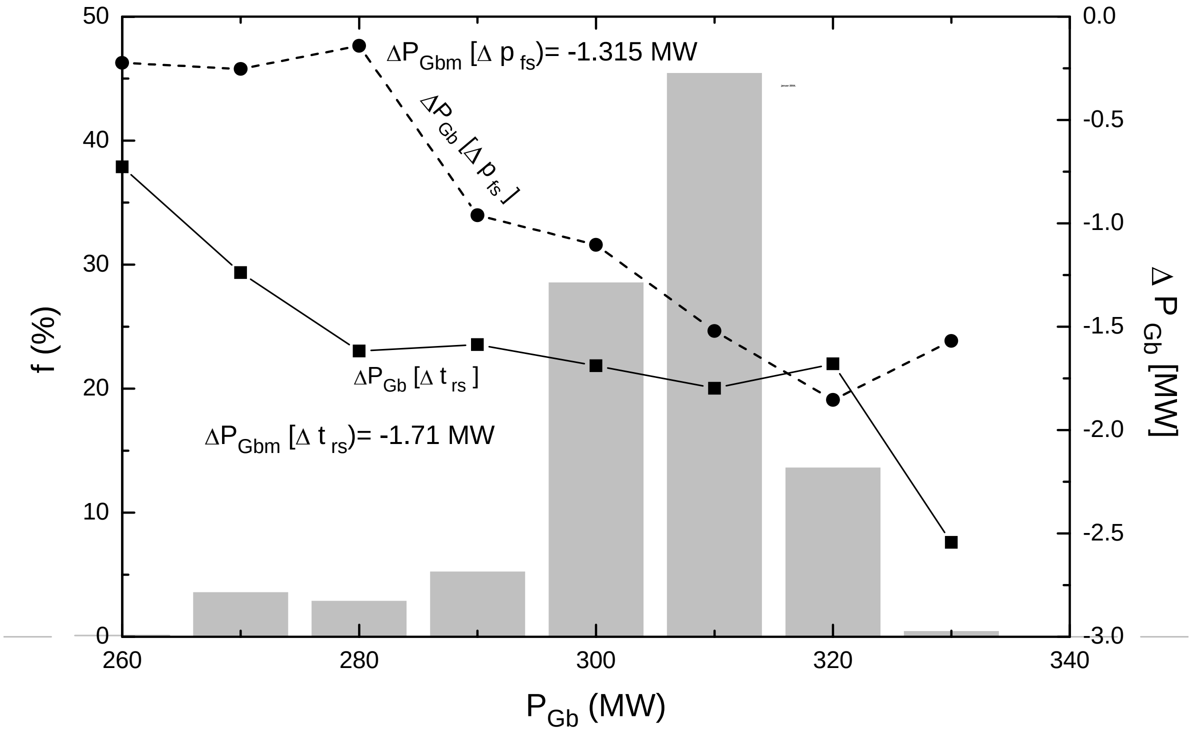

Fig. 9. Statistical results for load losses for fresh steam pressure and reheat steam temperature deviations

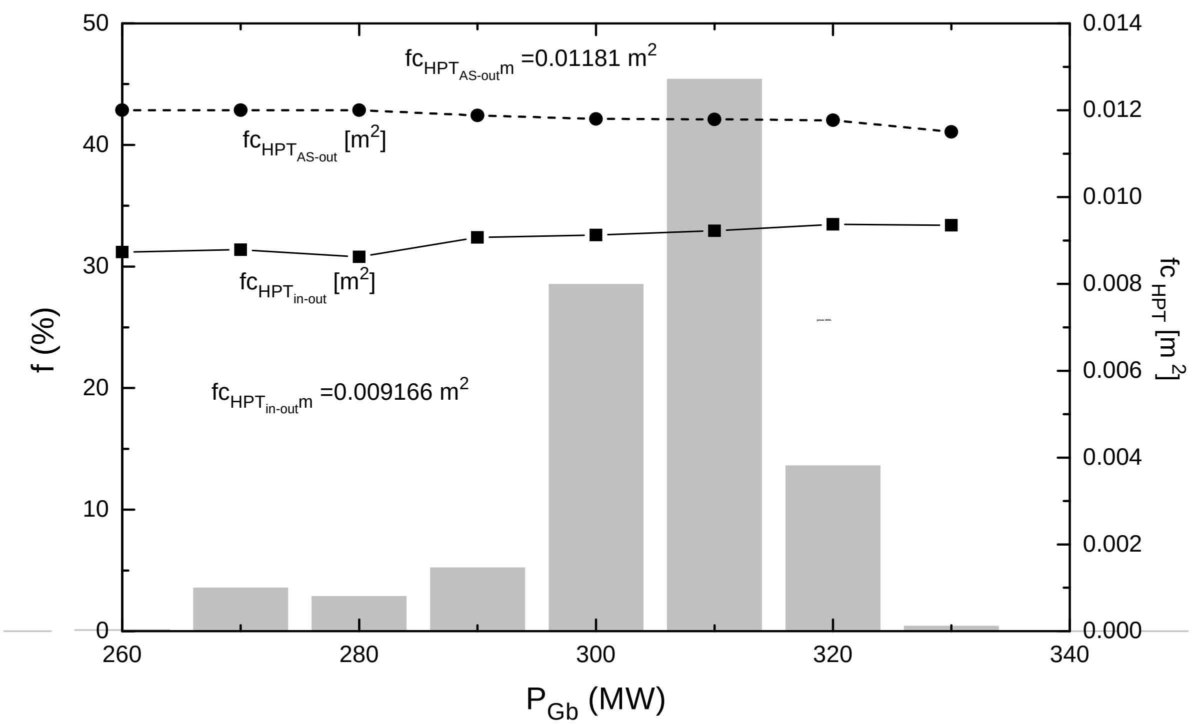

Fig. 10. Statistical results for flow characteristic constants for high pressure turbine

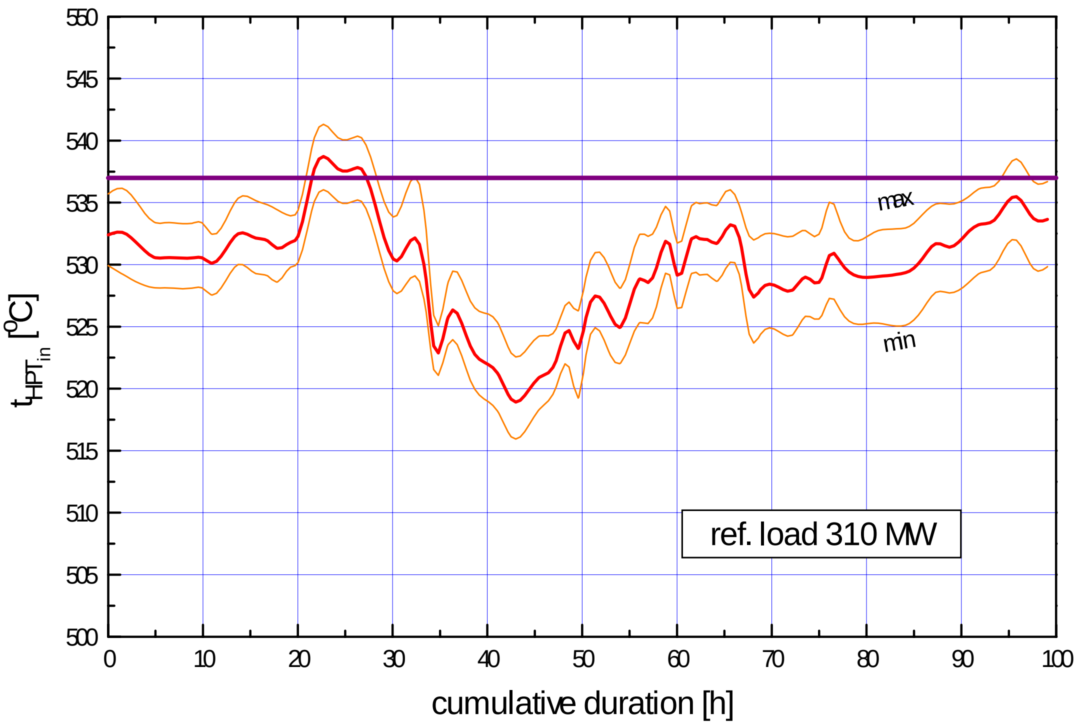

Fig. 11. Current trends for fresh steam temperature

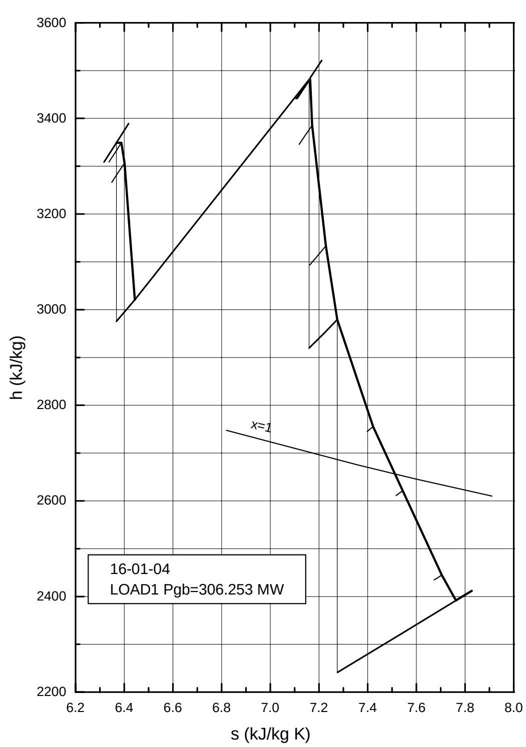

Fig. 12. Expansion line in steam turbine for the chosen "identified" load

Beside the basic curve for the mean value, there are also presented the current trend curves for maximal and minimal values of fresh steam temperature which give information about temperature fluctuations in operating conditions. Nominal level of fresh steam temperature is also drawn and it shows fresh steam temperature deviations in operating conditions.

Presentation of expansion line in turbine for chosen "identified" regime load is certainly very interesting – fig. 12. This presentation has been enabled thanks only to the corresponding developed methodological and software supported control of process.

3. CONCLUSION

Software system for diagnosis of operating conditions, control of economy and operating state of steam turbine unit provide:

- «identification» of steady regime loads and determination of mean values of processed parameters for identified regimes
- filtering or the investigation of validity of processed values for different parameters,
- calculations of deficiency process parameters and performances using the corresponding methodologies,
- permanent following of efficiency or heat rate of steam turbine unit and also the other important performances,
- complete analysis of the influences of parameters and performances deviations for identified steady loads on economy,
- calculations of current trends of different process parameters and performances for referent level loads,
- complete control of process which also enables getting the expansion line in turbine for the choosen identified regime,
- following the changes of operating states of different components of steam turbine unit,
- statistical analysis of regime loads and basic performances of steam turbine unit in a longer period.

The results presented in this paper are only one part of the large group of results which enable the process analysis in detail for referent steam turbine unit. They give an introspective inspection of steam turbine unit operation for the first time in our country. Some of the results are entirely new and originaly ones, for example, those for the control of operating state of turbine parts after the calculations of flow characteristic constants. Obtained results enable the control of losses in the steam turbine unit and they can be ranked according to their values and the possibilities of their control by planning the corresponding mesures for their decreasing. Beside the economy increases, thanks to this software system, it is possible to realize a better service agreement, higher reliability and availability of steam turbine unit, as well as its life made longer.

In the next phase, the development of software system for on-line diagnosis of operation of steam turbine block is planned for getting instructive information in real time for the possibility of intervention to improve the operation of steam turbine unit. Having in mind the specific role of this planned software system in the future, both of software systems would do their entierly different functions at the same time. On the other side they would supplement each other after their realized data bases.

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