

A novel approach to teaching diagnostics: an interactive 3D system *InterEdu*

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Abstract

The paper deals with an interactive application intended for teaching diagnostics of machinery and processes entitled Diagnostics and Maintenance of a Complex Object. The main idea of the application has been to provide and summarize as well as structuralize knowledge acquired by the students during their participation in the lectures of Methods of Technical Diagnostics. The programme of the lecture addresses general methodology of the diagnostics of machinery and processes, taking advantage of two most general approaches: model-based diagnostics (concerning mainly processes), and diagnostics with hidden models of objects that usually takes advantage of diagnostic relations between features of measured signals, and conclusions concerning technical condition of the object. Additional issues addressed in the application concern control of machinery, and maintenance. As a general object of diagnosis the thermal power station has been selected due to the complexity of the system as a whole and the possibility to recall many parts of material contained in the lecture.

1 Introduction

Technical diagnostics is a discipline of applied sciences that includes knowledge from many disciplines such as mechanics, general knowledge of machinery design and operation, measurements of physical quantities, signal processing techniques, methods of diagnostic inferring and many others. Engineers who practise diagnostics should possess both the theoretical background and skill acquired during practical operation with machinery and equipment, as well as measuring instruments, analysers and many others. Having this in mind, a group of researchers active in technical diagnostics headed by W. Moczulski decided to elaborate teaching aids for summarising as well as structuring knowledge acquired by the students during their participation in the lectures and classes of Methods of Technical Diagnostics. To this end, an interactive approach based on the powerful 3D InterEdu system [2] has been employed.

This paper deals with the application entitled Diagnostics and Maintenance of a Complex Object that has been prepared as one of more than 20 applications of the Interactive 3D Education System InterEdu. The project InterEdu has been carried out at the Faculty of Mechanical Engineering, Silesian University of Technology, under heading of Prof. Bożena Skołud in the period of years 2010-2012. The project has been supported by the EU in the framework of the national programme POKL (Operation Programme Human Capital). The core of the project consists in a methodology of presenting supporting material to the lectures and classes, as well as the system for making available this material to students of the Faculty. The system includes respective hardware and software with original 3D browser QuasarTM.

The paper is composed as follows ...

2 General conception

The authors were faced with the task of elaborating an application concerning diagnostics and exploitation of a complex object. Assuming that the object itself should be complex enough in order to require broad knowledge and skills of the students concerning different machinery and equipment, the thermal power station has been selected. A rough idea of the diagnostic system of a power station is explained in the Fig. 1 from [1].

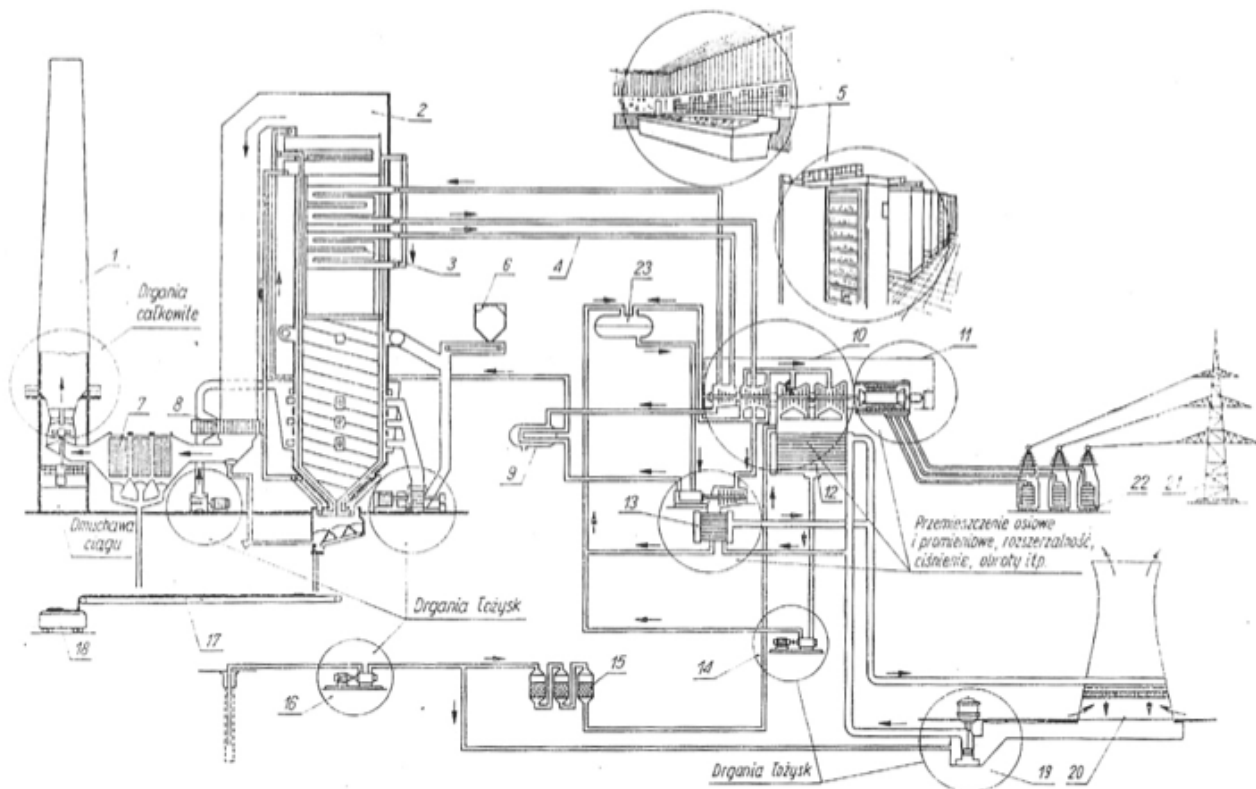


Figure 1: A system of vibratory surveillance of a thermal power station [1]

The main disadvantage of the decided solution is the complexity of the system, which could be easily overcome by selecting machinery, equipment and installations. However, there are many advantages, including:

- The possibility to study two main approaches to diagnostics model-based and model-free ones;
- The possibility to include several activities connected with the maintenance of machinery and equipment;
- The diversity of machinery involved in the system;
- The possibility to present some issues concerning control of selected subsystems of the thermal power station.

The authors collected the respective information basing on a modern thermal power station that has been put into operation in Poland in the last decade. Furthermore, a dramatic selection of possible types of machinery and equipment has been carried out taking into account the limited budget of the project.

To organise the work on the application in a systematic manner, the authors have created the meta-script of the session with the application (Fig. 2). While the application is launched, the main menu is presented, which organises the processing into four different aspects: *construction*, *operation*, *diagnostics*, and *control*. These aspects of the matter will be discussed in next paragraphs.

3 Menu Construction

The application is devoted to the students of the Faculty of Mechanical Engineering, who do not take part in the lecture concerning thermal power engineering. Therefore the goal of this part of the application has been to provide the students with the rough idea of the operation of the thermal power station, and with the physical system that converts the chemical energy carried by the coal into thermal energy carried by steam and, finally, into the electrical energy.

Main parts of this menu are: the *operation principle*, and the *virtual tour*. The second part is especially interesting since it allows virtual walk through a power station. Fig. 3 shows a bird-eye view of the power station. The interface allows the user to manipulate the view, changing the viewpoints and the temporary location of the observer.

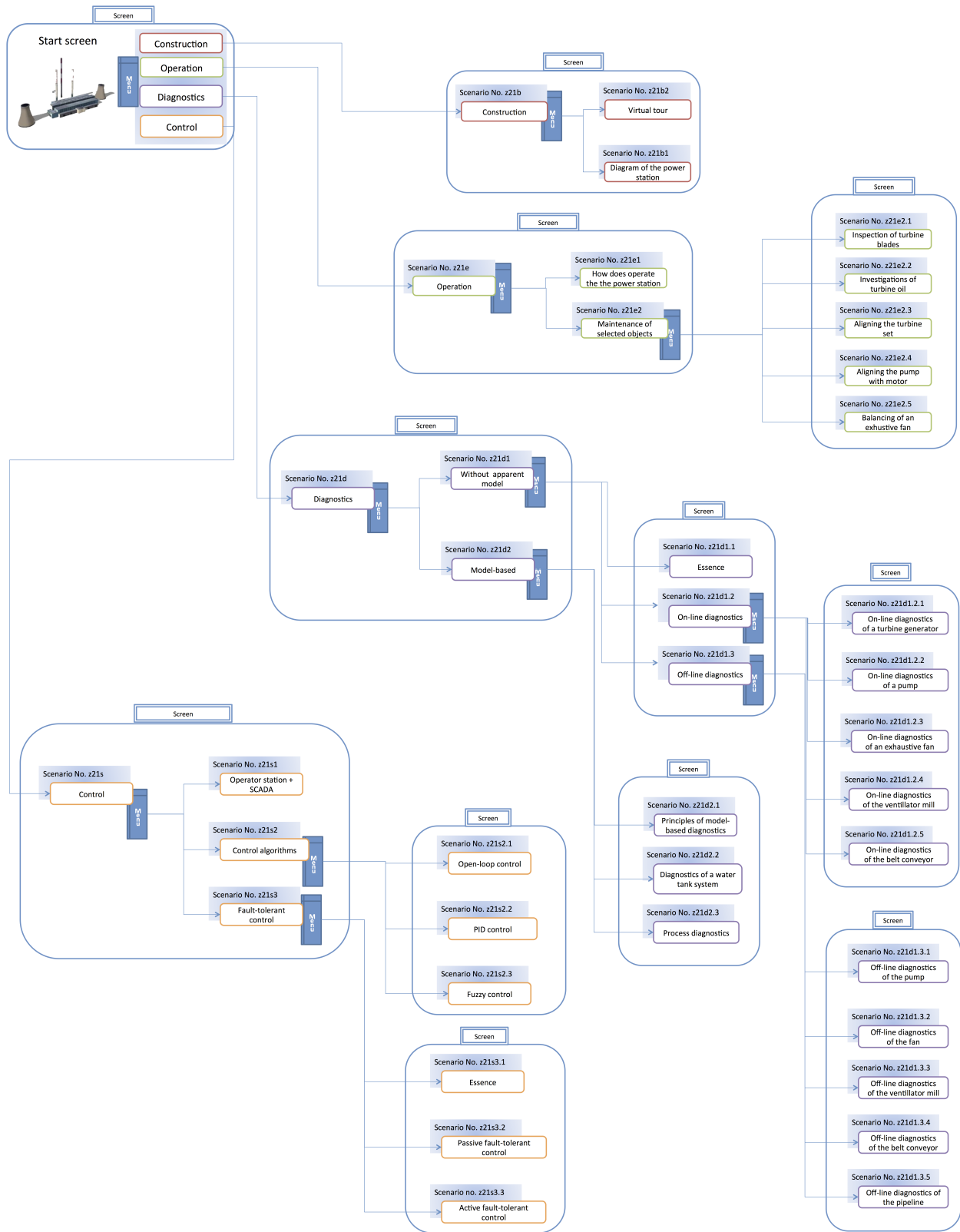


Figure 2: A meta-script of the application 'Diagnostics and exploitation of a complex object'

To allow the user to become better acquainted with the construction of the main parts of the power station, the application allows 'blowing' the walls and having the insight into the machinery and equipment installed in the building. Moreover, casings of the individual machines can be virtually dismantled showing internal parts such as shafts, turbine blades, bearings and many other.



Figure 3: A main view of the power station

The main goal of the ‘virtual’ tour is to present to the user the operation of the power station. The 3D interface allows manipulating with the view and location of the sight point. After completing the tour, the user

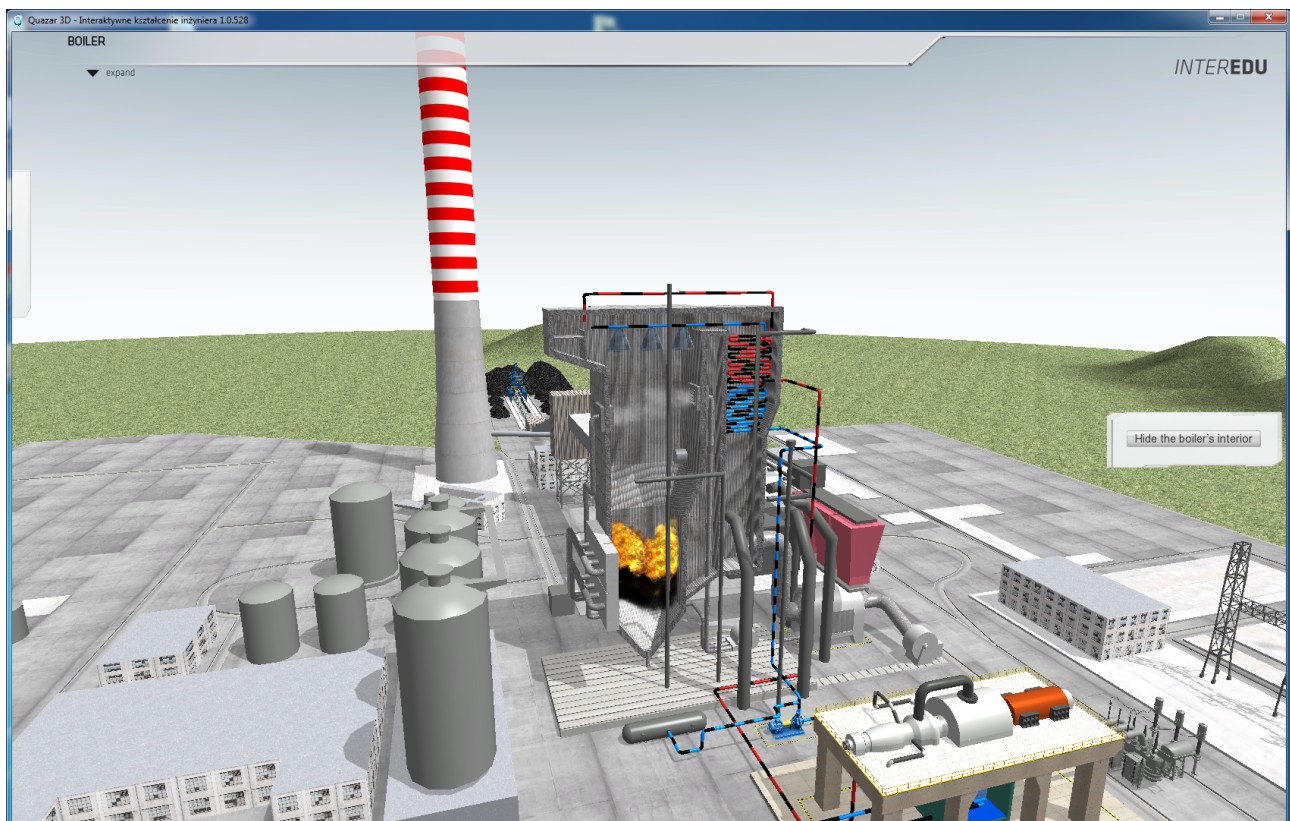


Figure 4: ‘Blown’ walls allow observation of several objects of the technological line of the power station

returns to the main menu of the application.

4 Menu Operation

Apart from explaining how the plant operates, this menu allows detailed analysis of the maintenance of exemplary machinery pieces. This includes:

- Inspection of the turbine blades;
- Investigation of the turbine oil;
- Alignment of the turbine set;
- Alignment of the simple pump/drive system;
- Balancing the exhaustive gases fan.

All these tasks are of interactive character, allowing the trainees to take several decisions concerning virtual operations on the given object.

As an example the task of aligning the pump/drive system is shown. Solving the task requires interactive operation of the user. Fig. 5 shows the (randomly generated) start situation, where the user begins the aligning procedure performing measurements of the relative location of coupling hubs applying simple gauges.

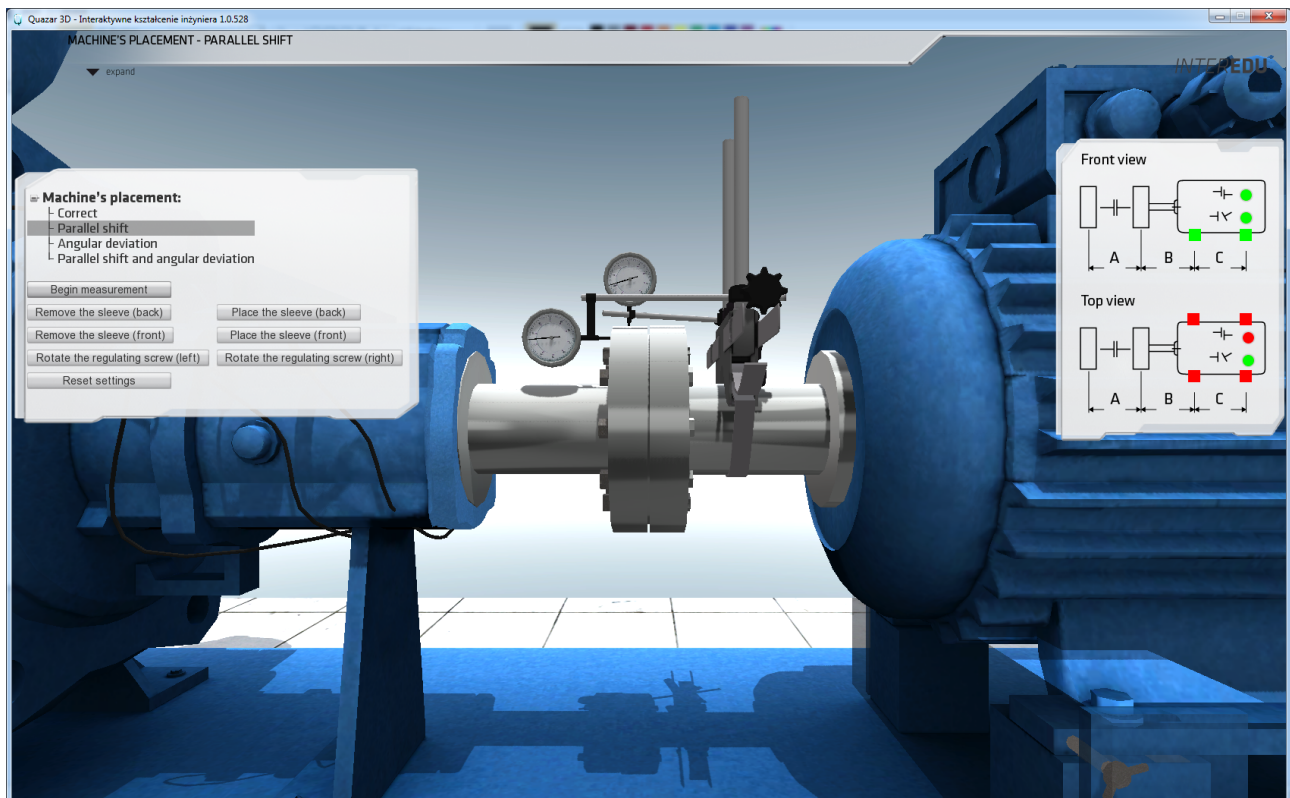


Figure 5: Aligning the pump/drive system: initial stage

Having measured the relative location of coupling hubs, the user is able to determine the respective numbers of washers (to align the system in the vertical direction), and to turn the regulating screws to achieve the alignment in the horizontal plane. The final result is shown in Fig. 6.

5 Menu Diagnostics

This menu concerns prevailing number of options. In general, two approaches have been implemented: the model-based diagnostics, and the model-free diagnostics (i.e. diagnostics without the apparent model).

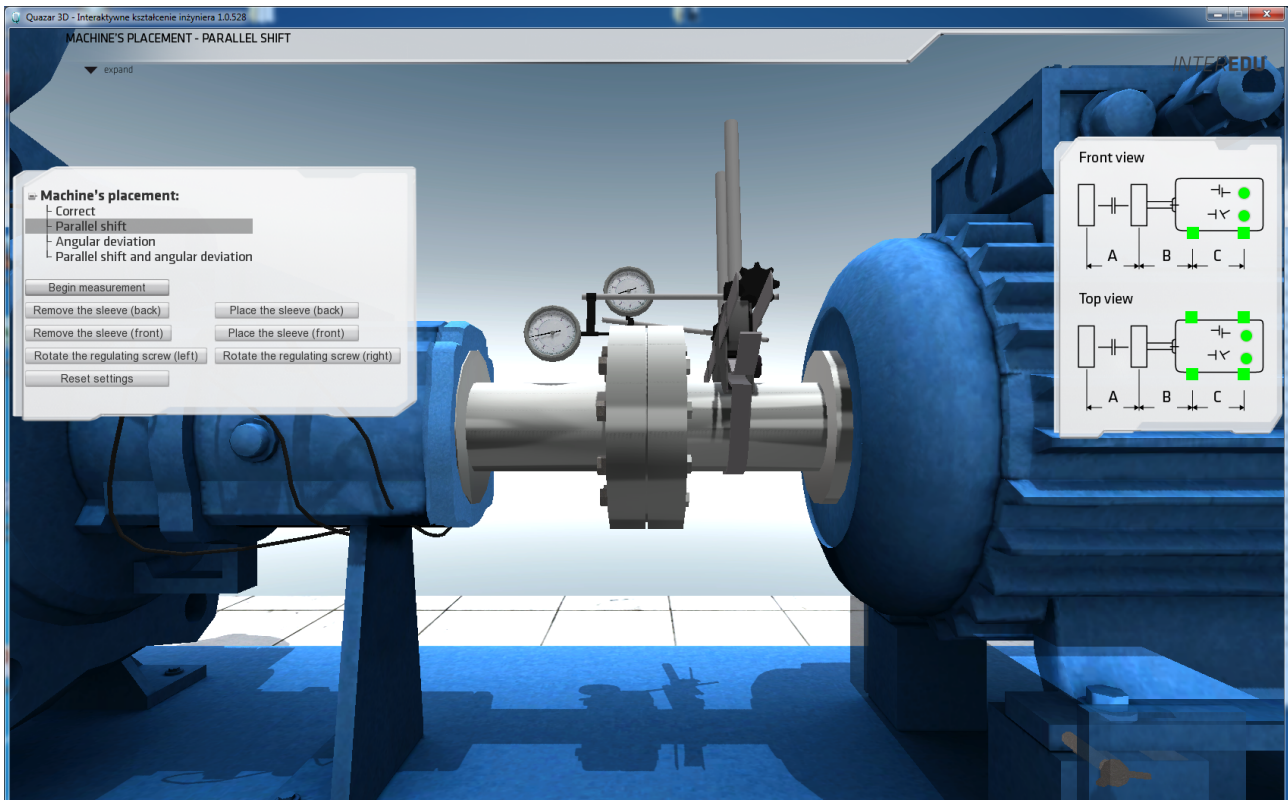


Figure 6: Aligning the pump/drive system: final stage

The scenario of this part of the application starts from the general view of the modern control room (Fig. 7). By the double-click on the SCADA screen the user enlarges this screen and is able to select objects that are included in the diagnostic part of the application (Fig. 8). This menu contains the objects and the considered faults.

The example presented in Fig. 9 shows the stage of resolving problems with the system of filters for water feeding to the steam boiler. The detailed diagram of the installation is shown. The user can invoke selected faults of the system. The diagnostics is based on the model of the subsystem.

To give a brief overview of the model-based diagnostics let us have a look at Fig. 10 that presents the complete water feed system. On the left-hand side there is visible the menu that allows selecting faults of sensors, actuators and the installation. After choosing some fault the second screen is presented showing the SCADA screen with the synoptic scheme of the installation (Fig. 11), where the fault is easy to identify.

The user can watch the plot of residual whose course reveals the time of occurrence of the sensor fault (Fig. 12). The picture shows also upper and lower limits that are used to classify the residuum in order to obtain the diagnostic signal informing about the fault.

It is worth stressing that the application takes advantage of dynamic input-output models in the form of the neural networks. Such an approach required quite reasonable amount of work spent for preparing realistic models of the pieces of the installation.

More issues are concerned with the diagnostics without apparent model. The approach has been divided into two different kinds of diagnostics, depending on the way the data is acquired from the object to be diagnosed.

In case of critical machinery there are installed specialised stationary sensor systems, and data is collected by SCADA system, that takes place exemplary in case of the turbine generator (Fig. 13). The results of diagnosing are presented on the screen of the SCADA system (Fig. 14).

In case of the auxiliary machines, and also sometimes by critical ones, one collects signals and estimates values of the signal using hand-held measuring equipment such as specialised signal analysers and many others. Fig. 15 shows an attachment of the accelerometer to the conveyor's frame, while next one (Fig. 16) shows the amplitude spectrum obtained by means of the signal analyser. The shape of the spectrum is based on the relevant diagnostic literature.



Figure 7: General view at the control room of the virtual power station

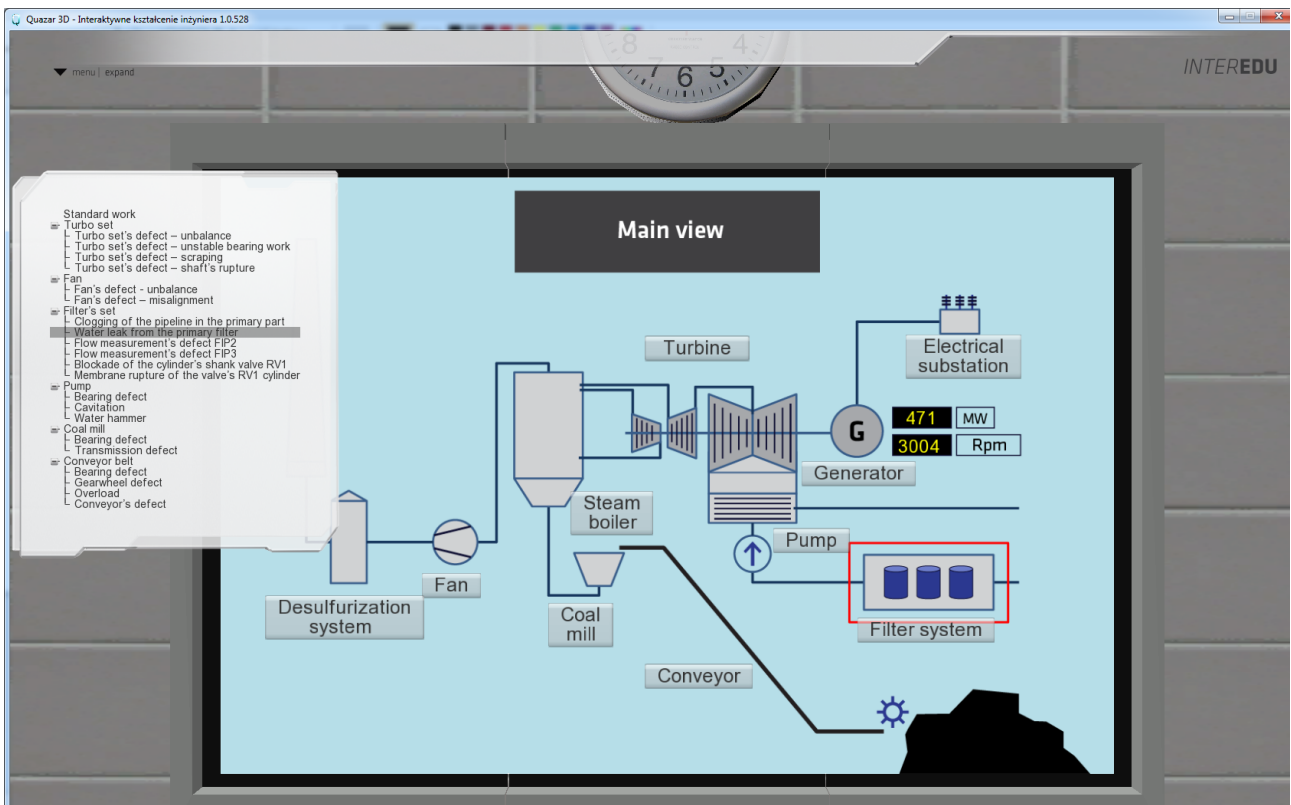


Figure 8: View on the SCADA screen and the Submenu 'Diagnostics'

6 Menu Control

The application includes also several tasks concerning control. Three basic approaches to the control of the object are addressed: control in the open loop, PID control, and application of a fuzzy controller. In Fig. 17 the

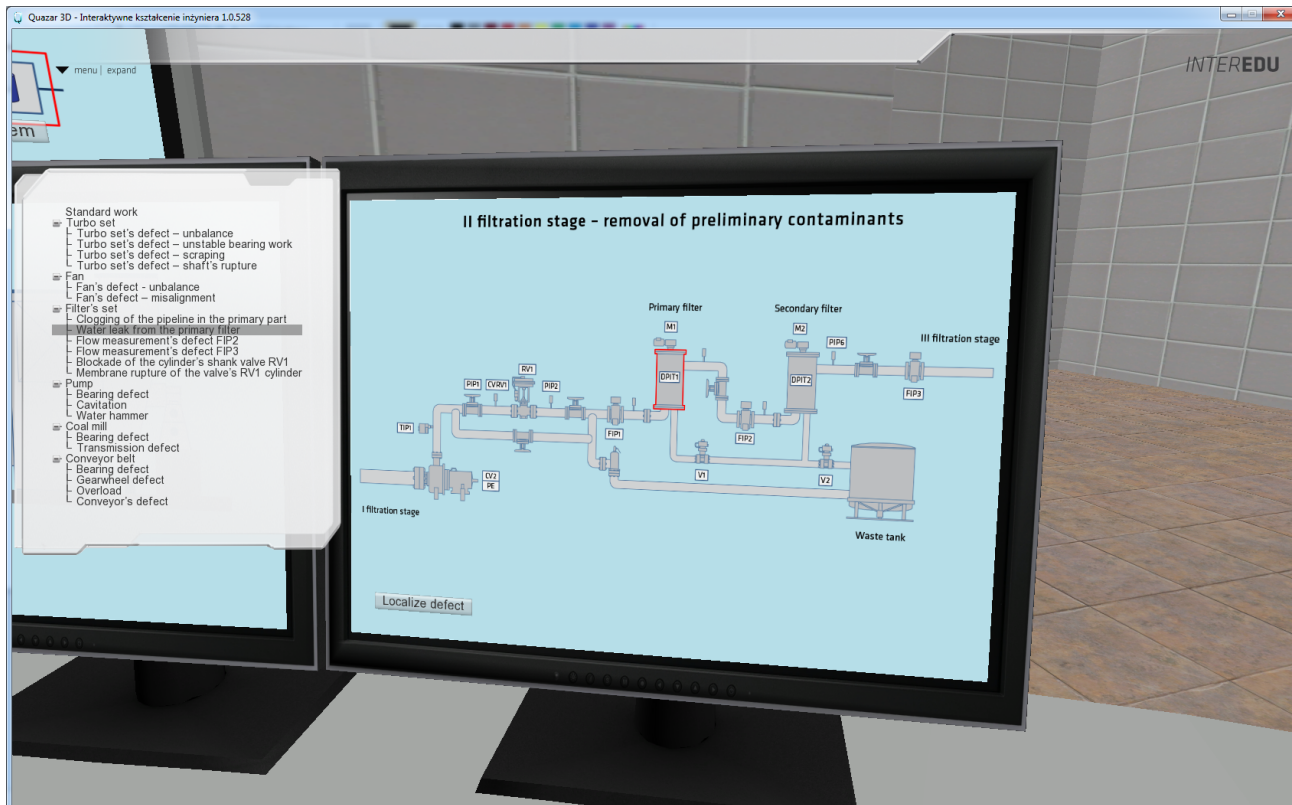


Figure 9: Diagnosing the system of filters for water feeding to the steam boiler

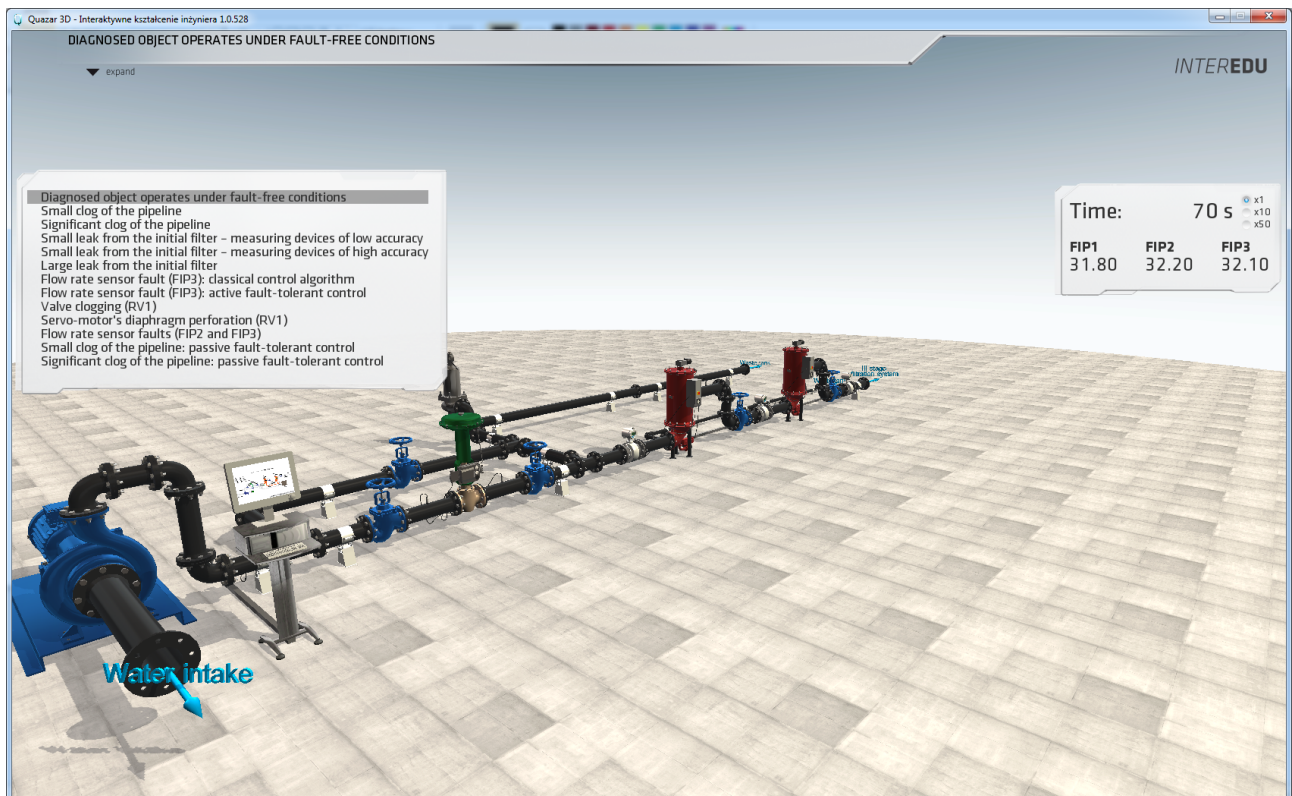


Figure 10: General view of the system of filters for water feeding to the steam boiler and diagnostic menu

structure of a fuzzy controller of a deaerator is presented, basing on the Mamdani model.

Due to an interactive interface of this part of the application the user can modify parameters of the controllers and observe the behaviour of the unit controlled by this controller.

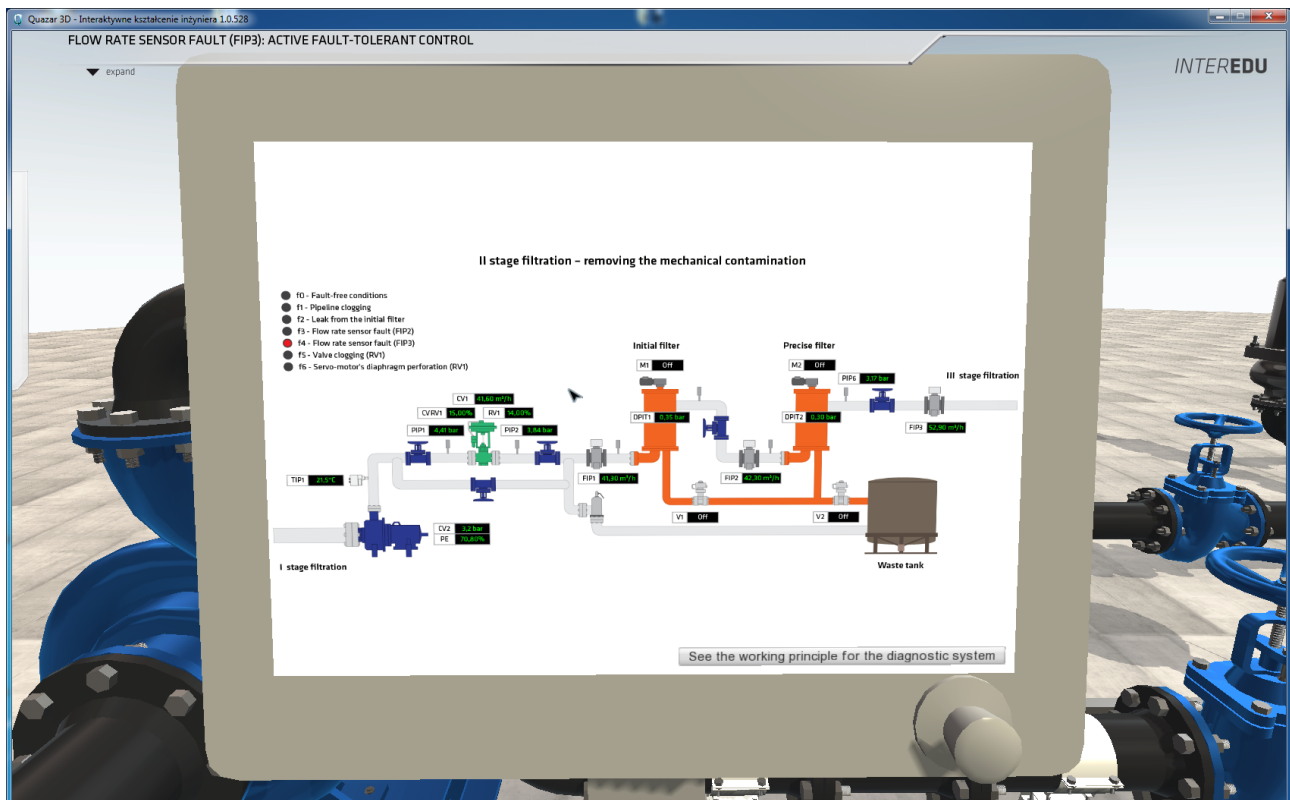


Figure 11: SCADA screen of the system of filters for water feeding to the steam boiler

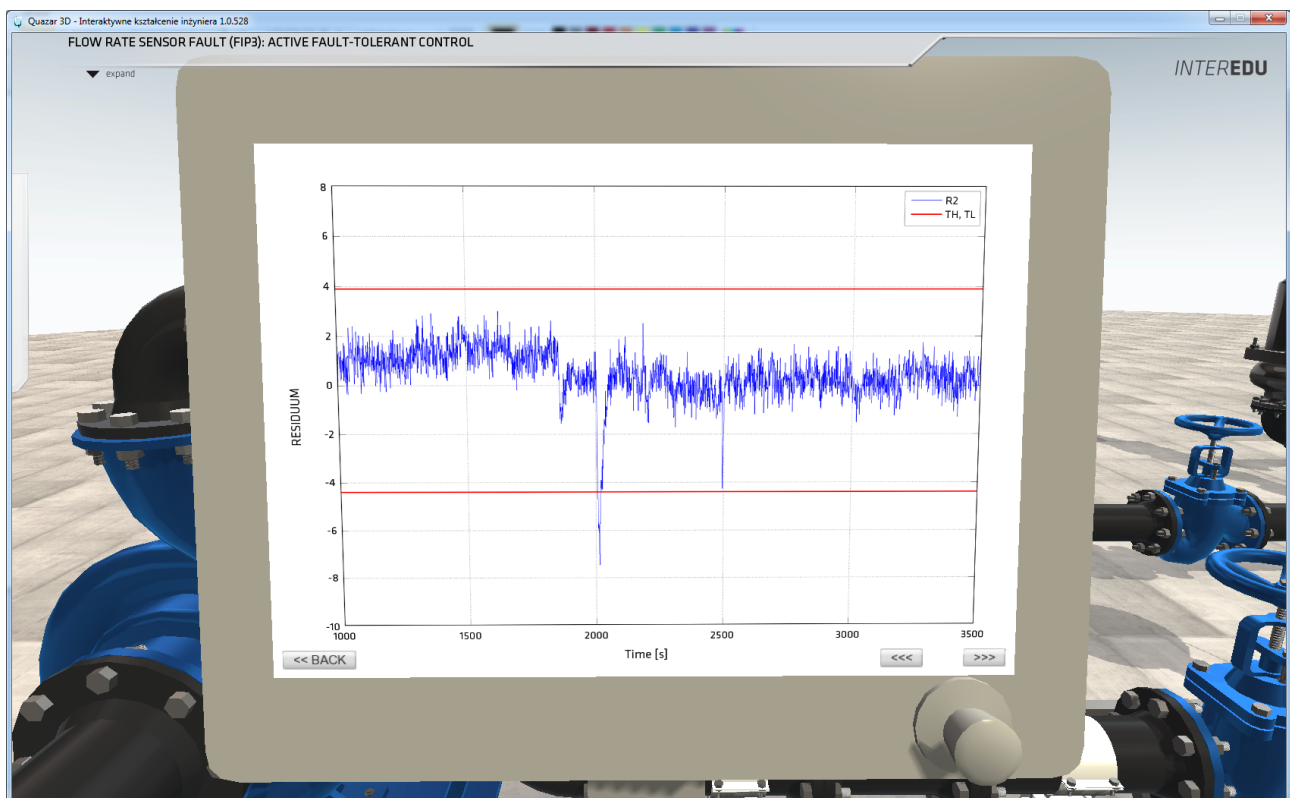


Figure 12: SCADA screen of the system of filters for water feeding to the steam boiler

7 Recapitulation and conclusions

The paper dealt with a novel approach to teaching technical diagnostics, whose essence consists in the building of a 3D application that allows immersing the students into complex virtual object which is the power

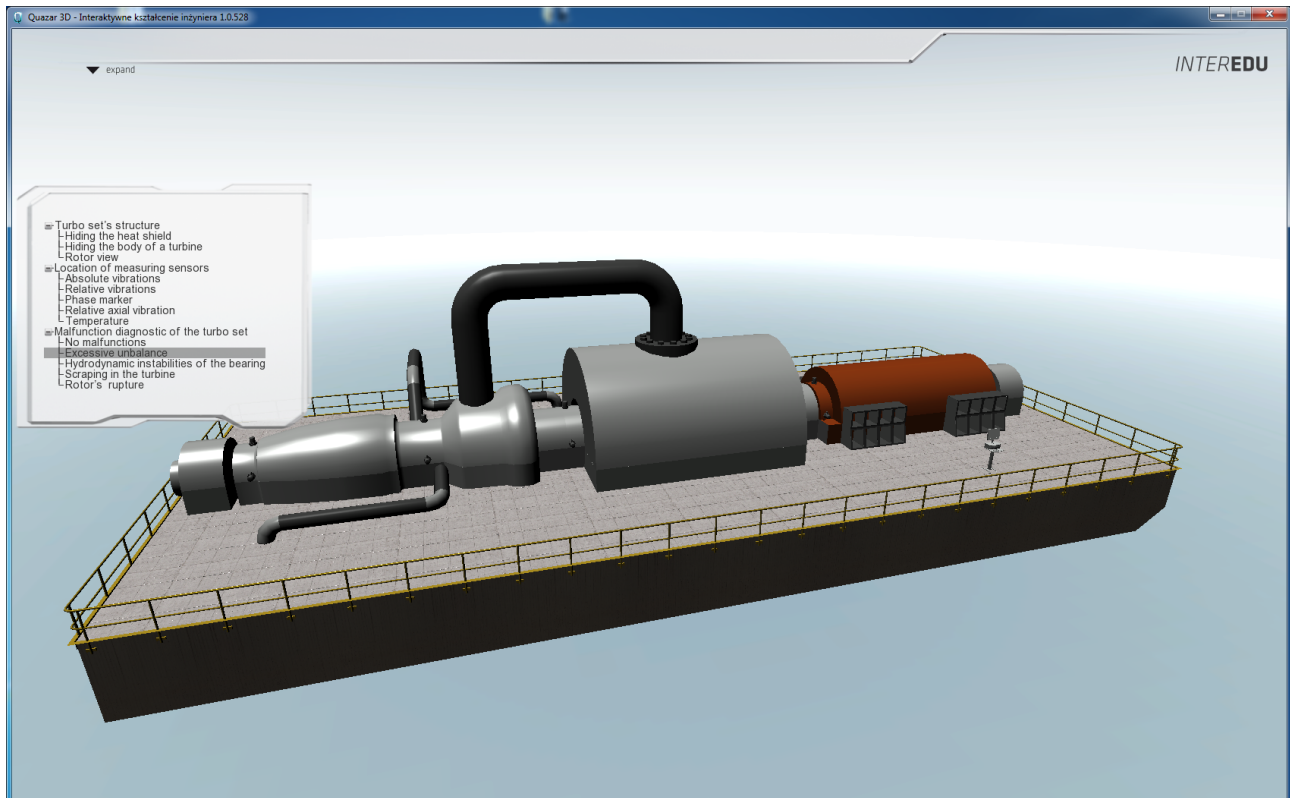


Figure 13: General view of the turbine generator

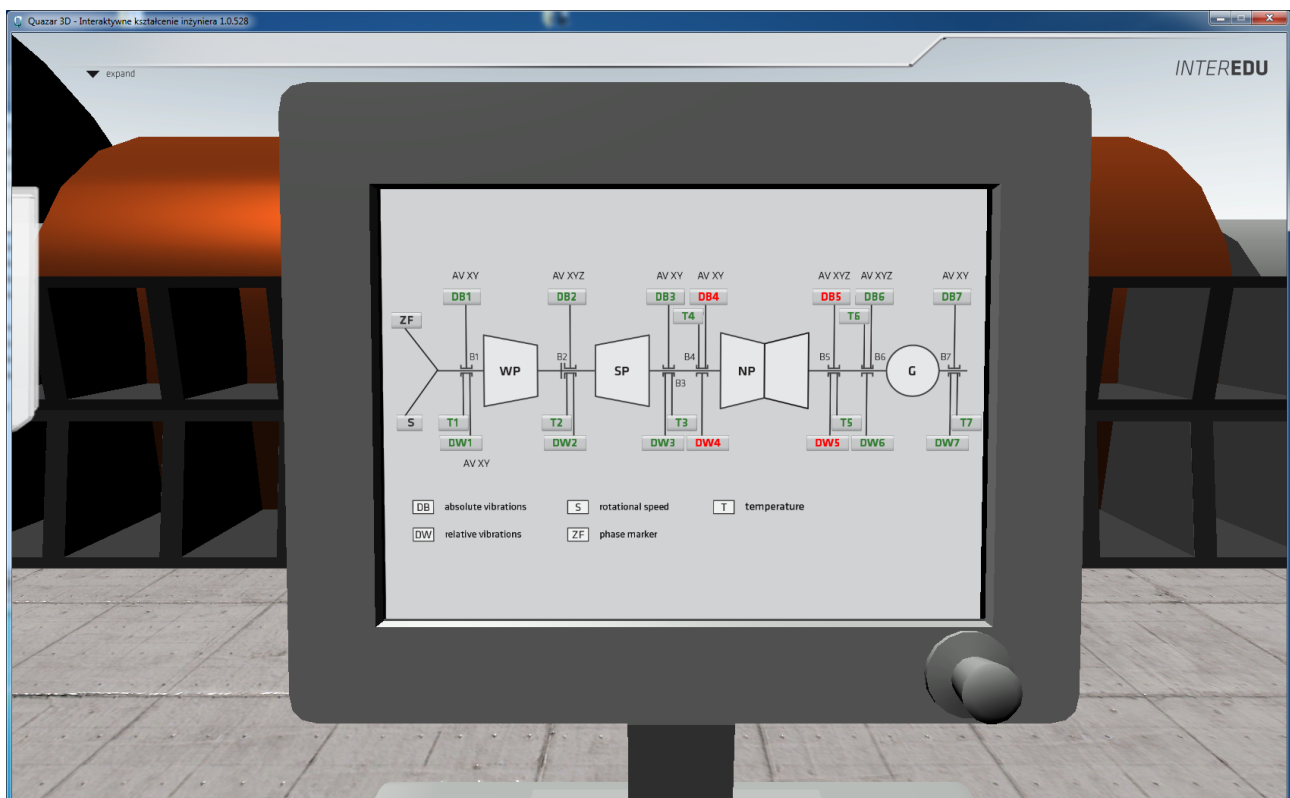


Figure 14: Results of the monitoring of the turbine generator presented at SCADA screen

station. To this end, the special application has been built. The core of the application constitutes the 3D browser called Quasar 3D.

The broad field of problems is organised into four aspects: *Construction*, *Operation*, *Diagnostics*, and *Control*. The diagnostics aspect is the most comprehensive, since it includes the model-based diagnostics and the

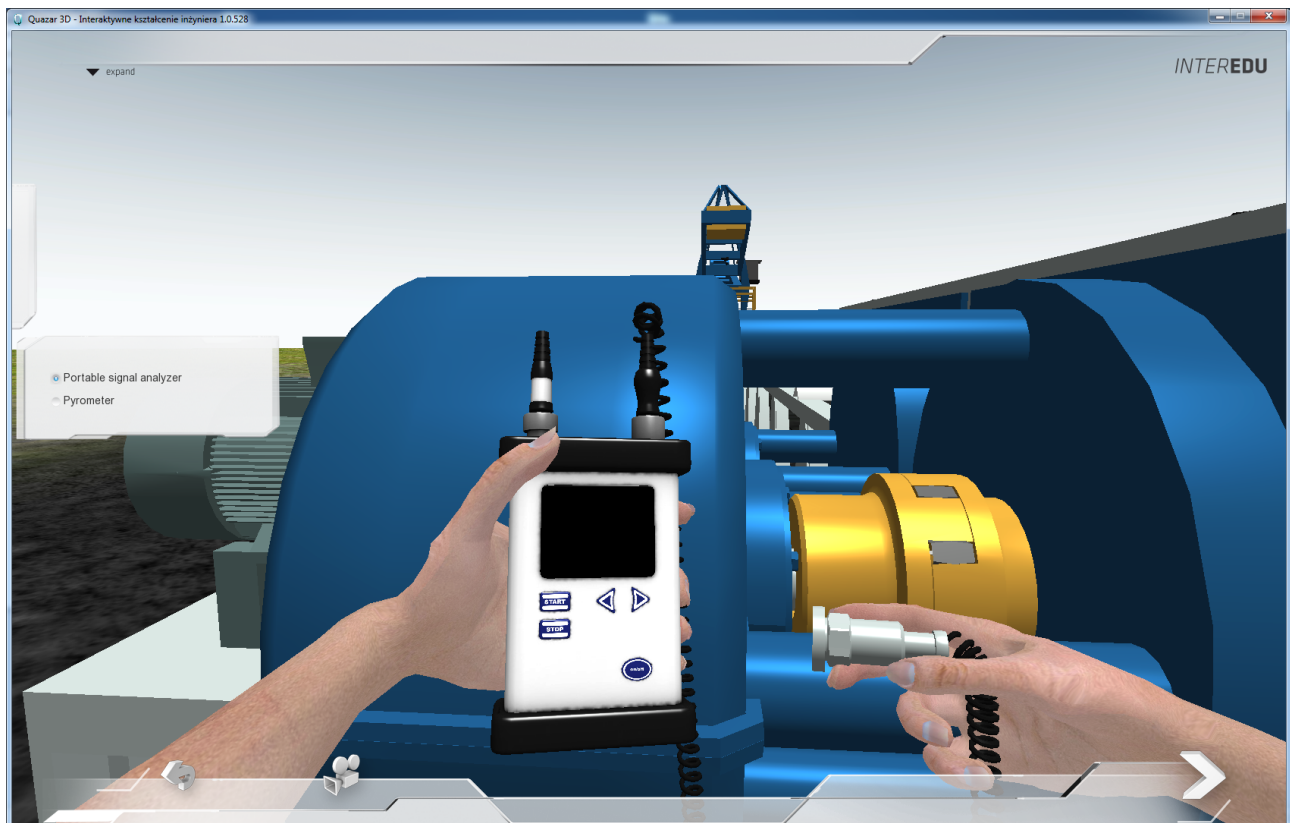


Figure 15: Selection of a measuring point at the frame of the belt conveyor

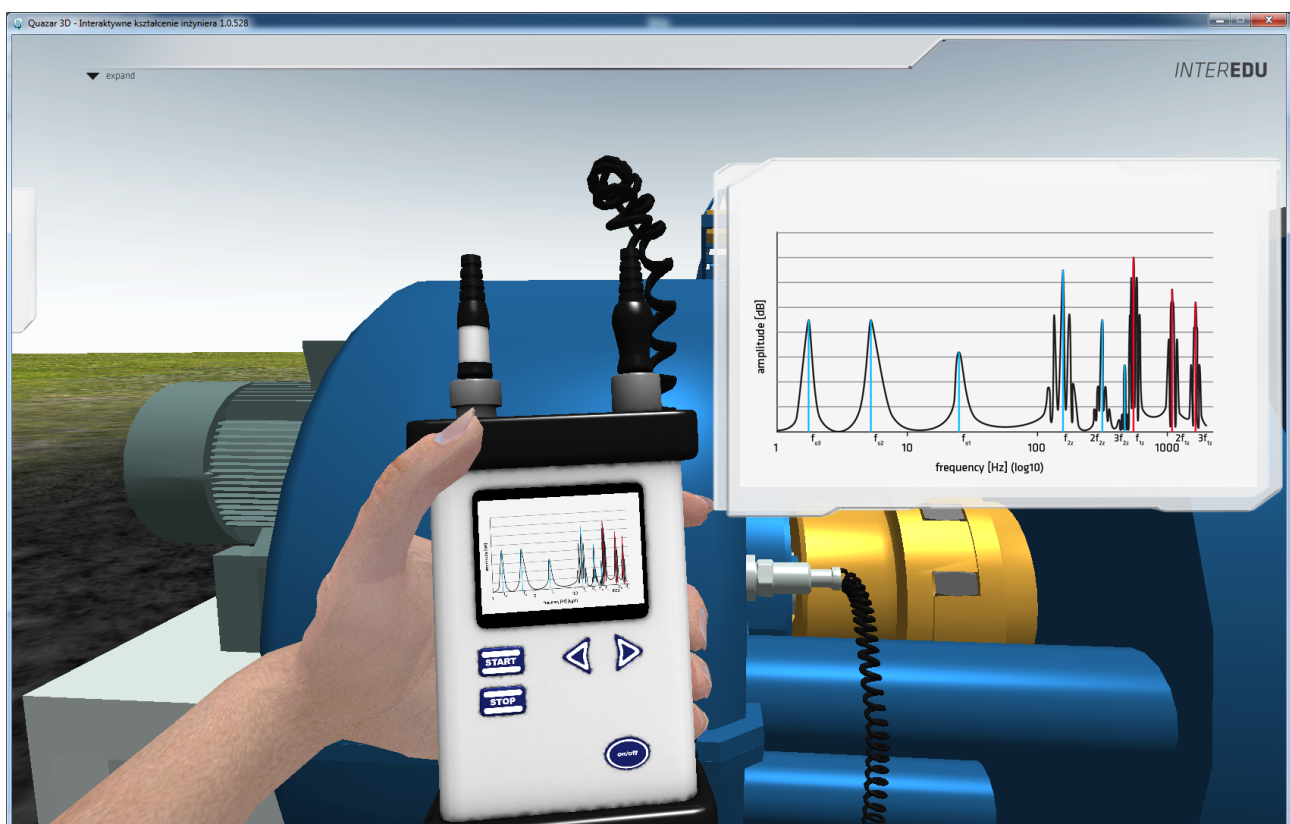


Figure 16: Exemplary amplitude spectrum of vibrations measured at the frame of the belt conveyor

diagnostics without the apparent model. Two distinctive approaches to the latter diagnostics are implemented: diagnostics basing upon the stationary measuring/monitoring system, and diagnostics based on the handheld

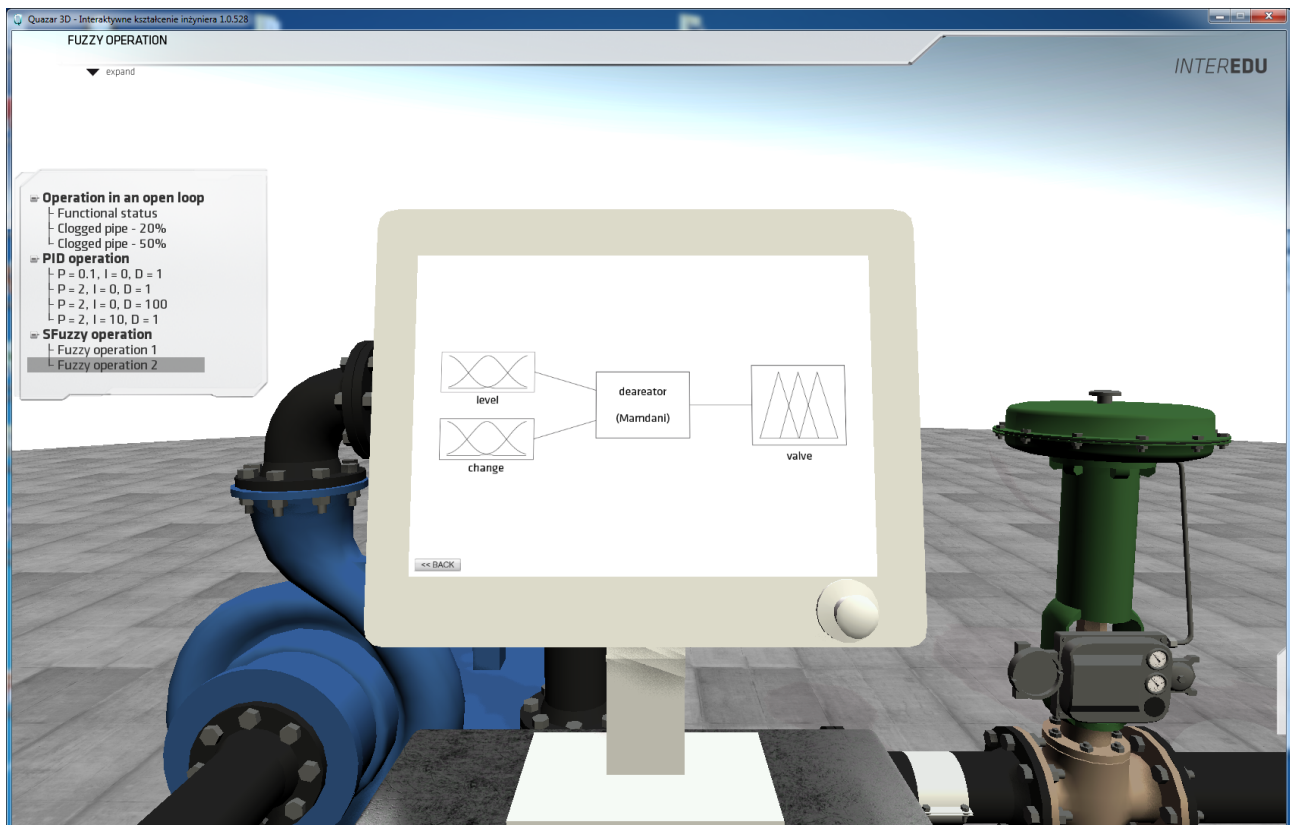


Figure 17: Structure of the fuzzy controller of the deaerator

measuring equipment. Finally, some aspects of control are made available to the user.

The application is used in the course of ‘Methods of Technical Diagnostics’ at the very final stage of the lecture, when the students have collected knowledge about general methods and techniques, as well as specific techniques connected with the machinery types. It has been proven that the application helps in systematising the students’ knowledge. The application allows the students to operate in the virtual plant and to solve problems very similar to those they can be faced with in the industry.

The project can be continued in several dimensions. For example, novel pieces of machinery can be included, as well as other diagnostic techniques applied. However, special attention should be paid to the interactivity, whose role is especially important, because students are more interested in the usage of the application and are able to gain a kind of experience in diagnostics and maintenance of different pieces of machinery.

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