Multiparameter Control of a Cross-Flow Turbine

Stanimir Y. Yordanov[1], Krasimir H. Ormanzhiev[2]

Abstract: **In this paper a general structure of a computer-implemented, object-oriented software system is describe. The system uses the intelligence mechanisms and is intended for the control of technical objects that function both in predictable and random environments. The object for studying is automatic system is made of a turbo the pump, a complex pressure pipeline, cross-flow turbine and electric generator. The results of experiment have been presented in graphical curves.**

Keywords: **Real-Time problems; RTS System Kernel functions; centrifugal turbo-pump; pressure penstock; cross-flow turbine**

I. Introduction

The study of dynamical processes in pressure turbo-system at parallel work of the hydraulic turbo-alternator fed by means of a common pressure penstock is of great significance during design and optimization of the operation of such equipments as water-power stations, pumping stations, etc. [1, 2, 4].

During system adjustment unestablished (dynamical) processes originate [3, 5, 6]. The maximum pressure rise in the pressure penstock has to be limited by consideration for the strength dimensioning of the penstock as well from the point of view of the quality of turbine adjustment

The requirements towards governors of the water turbines are quite various as well as they are conditioned by the special features and variety of their modes of exploiting, i.e.:

- work in energy-system with high power;
- work in isolated energy-district;
- work of idle stroke;
- work at unloading with switching off the generator from energy-system.

At the up-to-date energy-system, the automatic governors must possess not only high qualitative parameters in connection with supporting the values of revolotions of the turbines but in the best way to react on all governing influences.

II. Description of The Developed Stand

The stand scheme for experimental study of pressure turbo-system is shown in Fig.1. It consists of the following elements: 1 – reservoir; 2 - vacuum gauge; 3 - entrifugal pump; 4- electrical motor; 5, 8, 14, 17, 18, 20, 22 – sensor for low pressure**;** 7, 9, 10, 12, 13, 30, 40 - valve door; 24 - cross-flow turbine;15- ADC/DAC; 16 – personal computer; 19 - valve door and electrical motor; 20 - block for generator loading; 28 - three-phase synchronous generator; 33 - electrical motor; 36,37-sensor for high pressure**;** 38-hydrostation; 39 - suction valve; 34, 35 - suction valve;41- sensor for position of the input valve; 32 - auxiliary centrifugal pump; 31 – contact manometer;29– tachogenerator; 42- hydrocilinder; 25 control panel for power;26 – block for loading of the synchronous generator; 27 - driving belt; Depending on the situation of valve doors 11 and 12, scheme with long or short pressure penstock can be realized. In the two cases, parallel working hydraulic turbo-alternator is imitated by passing the working fluid from the pressure penstock through the valve door 18.

A scheme with short pressure penstock is realized at open valve door 12 and close one 11.

The supplied flow from centrifugal pump joins in the short pressure penstock (with diameter d=200 mm) as one part passes through the water turbine but the other one – through the valve door 18.

A scheme with long pressure penstock is realized at close valve door 12 and open one 11. The penstock sector between 11 and 13 valve doors is made of polyvinyl chloride (PVC) with diameter d=100 m and length *l*=48 m.

The disturbances in the system can be supplied in consequence of the alteration of the valve door 18 situation or by the variation of the adjusting blade situation of turbine. The alteration of electric load only influence on the revolutions of the turbine and generator but not on the pressure and flow in the pressure penstock. This is due to the fact that the water turbine is active and a governor, which is used to compensate the variation of the revolutions by means of rotating the input blade, is missing. For realizing the control, apparatus-programme system, which is composed of primary transducer, programmable controller, personal computer (PC) and software for controlling, is developed.

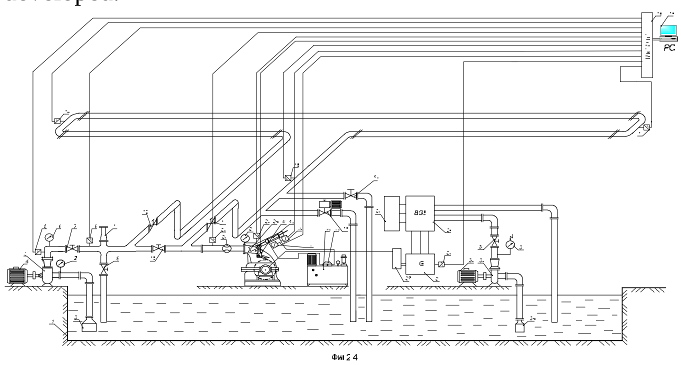

Fig. 1: Scheme of the stand

For accomplishing the observation, three sensors are used as follows: two ones for pressure of a type *PS3310* and one for revolutions of a type *PIVTM6*. By means of the sensors for pressure, the flow pressure is observed at the beginning of the penstock immediately after the pump and the flow pressure at the beginning of the water turbine (Fig.1). By means of the tachogenerators the turbine revolutions are kept up with. The signals, received from sensors by means

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of the controller *ADDA-12*, are transformed in digital signal as well as they are supplied to PC for processing. After analysing the received information control signals are elaborated. The controller support observation simultaneously on 16 analogue and it has ones analogue output. The signal transformation is performed by means of 12 bit analogue-to-digital converter for the eight channels as well of 12 bit analogue-to-digital converter for the remaining 16 inputs. The input signals are in the range of 0-5V for the sensors of a type *PS3310* as well of 0-10V for the sensors of a type *PIVTM6*.

The measurement accuracy depends on many factors as follows:

- the transformation accuracy for 8 bit analogue-to-digital converter is 0.01953125V, which is equivalent to the pressure in the order of 1.953125.103 Pa or for the revolutions of the water turbine – 6.06 min-1; the transformation accuracy for 12 bit analogue-to-digital converter is 0.0012220703125V, which is equivalent to the pressure in the order of 1.2.102 Pa or for the revolutions of the water turbine – 0.36 min-1;
- errors caused by disturbances along the trace. These disturbances depend on the line length, the length and type of the cable for connection between the sensors and controller. The availability of strong electromagnetic fields in the close proximity to the line for connection exerts an influence on the accuracy.

For example, the signal received by the sensor for pressure on the penstock input is highly become noisy because of the sensor nearness to the engine driving the water pump. The signal by tachogenerator is influenced by the electromagnetic field made by the generator.

For diminishing the effect of the parasite noises and for improving the measurement accuracy, 12 bit analogue inputs are used as the signals before entering in them, passes through low-frequency filters for the disturbance compensation. The scanning cycle is determined by the following factors:

- time for signal transformation by analogue-to-digital converter (26µs per one input);
- time for data processing by the controller;
- time for analyzing the i/o commands supplied to the controller by PC;
- time for data transmission between controller and PC.
- time for information processing by PC, etc.

For compensating the effect of the parasite signals and for improving the response time it is worked in the following directions:

- designing of controllers for signal transformation by the sensors which will be placed in maximum proximity to the transducer. Thus, the disturbances along the connection between controllers and sensors will be eliminated; the time for signal transformation will be reduced because of parallel execution of the operations under transformation.
- variation of the interface for connection between controllers and PC.

III. STRUCTURE OF A SOFTWARE SYSTEM

The control of the system is based on the object oriented system "Cunami" (fig. 2). Cunami is a system of hight precision class, developed for control of technological processes and active quality monitoring. This system is developed for Window NT. His module structure is well appropriate for treatment of a large class of problems.

The plant control is fulfiled by control module with an multiparameter control law. After analising of all processes and all perturbations in the system the following variables were included in the control law:

- generator speed;
- position of the blade on the input of the water turbine;
- pressure on the input of the water turbine;
- pressure on position 18.

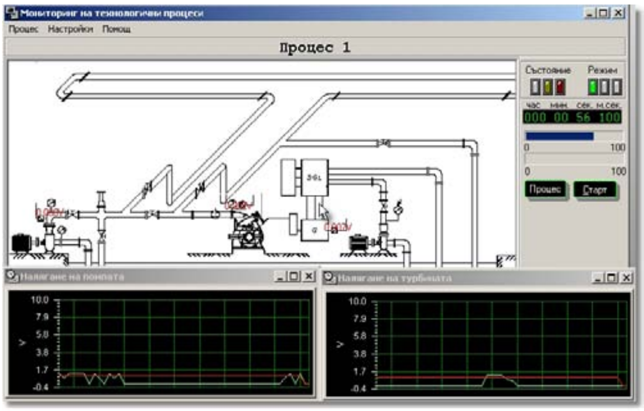

Fig.2. Control module

At this stage the electrical parameters of the generator are not included in the control law. However they will be included later. The structural scheme of the controller is shown on Fig. 3

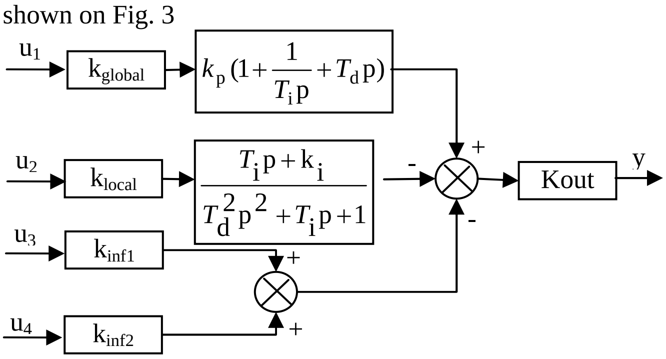

Fig.3. Structure of the controller

The controller is realized according to the following recurrent equation:

$$u(k) = k_p \left\{ \begin{matrix} e(k) + \frac{T_0}{T_i}\sum_{i=1}^{k} e(i) + \frac{T_0}{T_i}[e(k) + \\ +3e(k-1) - 3e(k-2) - e(k-3)] \end{matrix} \right\} \quad (1)$$

In real life conditions a hight level of noise is observed. Our analysis shows that this noise is in relatively restricted frequency band. However for decreasing of his influence software sensors are realized in real time according to the following transfer functions:

$$W(z^{-1}) = \frac{b_0 + b_1 z^{-1}}{1 + a_1 z^{-1}} \text{ and } W(z^{-1}) = \frac{b_0 + b_1 z^{-1}}{a_1 + a_1 z^{-1} + a_2 z^{-2}} \quad (2)$$

As a result the noise level has been reduced in an admissible range for stable functionning of the control

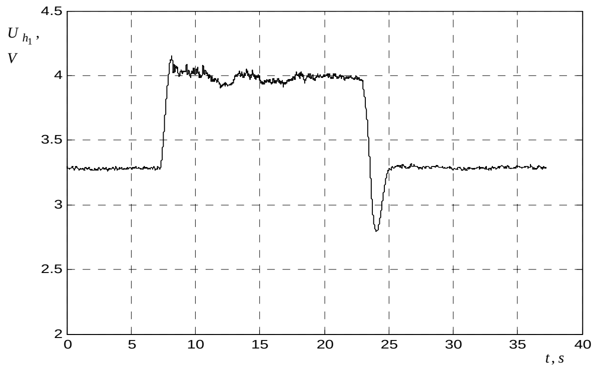

Fig.4a. Pressure of output the pump

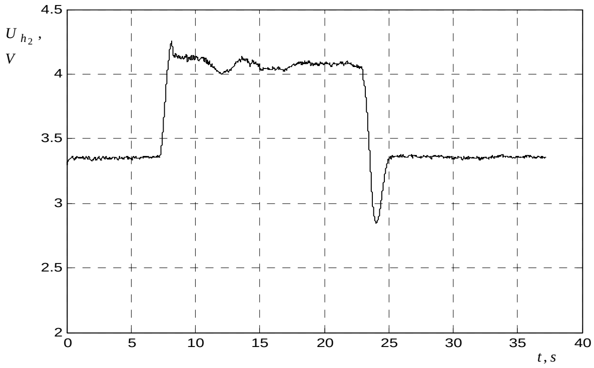

Fig.4b. Pressure of input the turbine

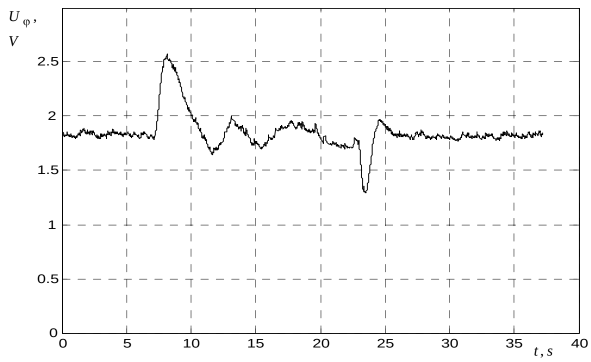

Fig.4c. Turnover of the generator

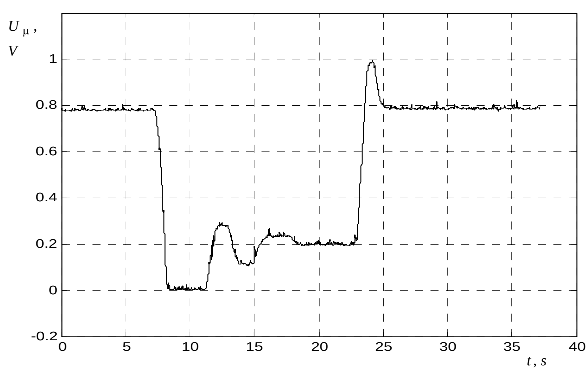

Fig.4d. Position in blade of the water turbine

Fig. 4. Automated control system with short pressure pipeline transient behaviour in the case of step change of the cargo instant

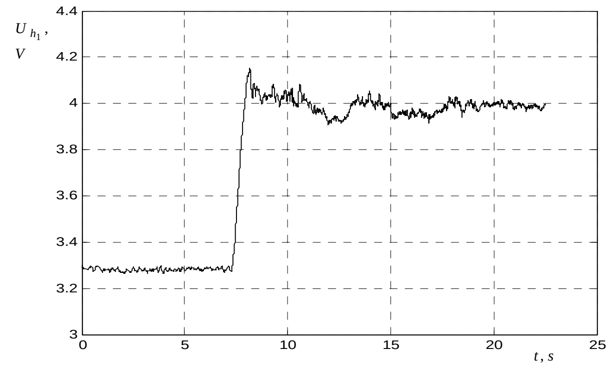

Fig. 5a. Pressure of output the pump

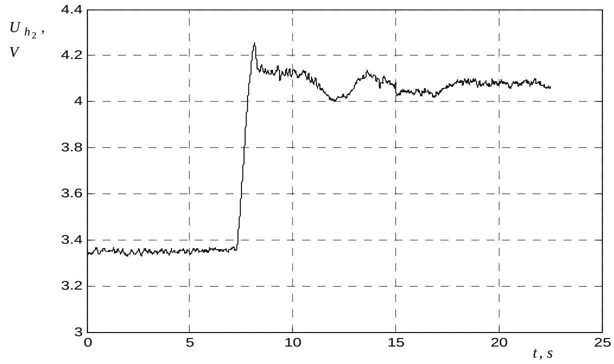

Fig.5b Pressure of input the turbine

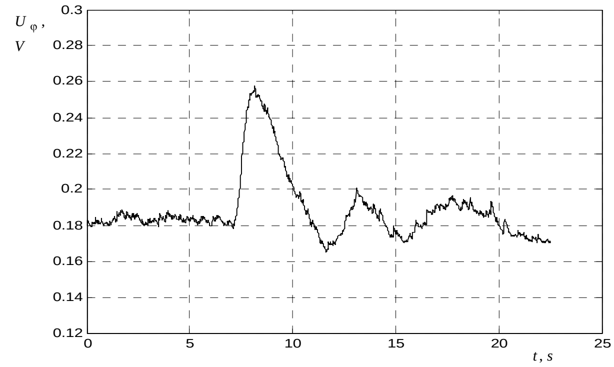

Fig.5c Turnover of the generator

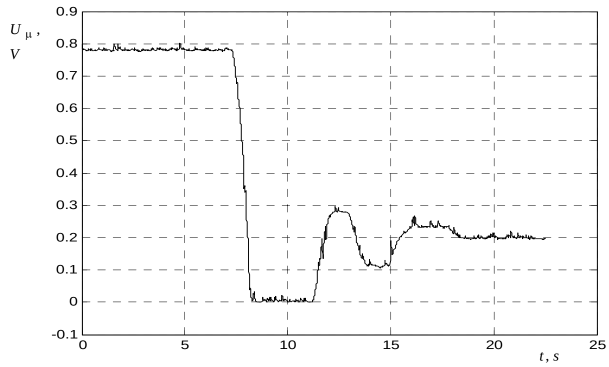

Fig.5d Position in blade of the water turbine

Fig.5. Processes in the system at unloading of the generator

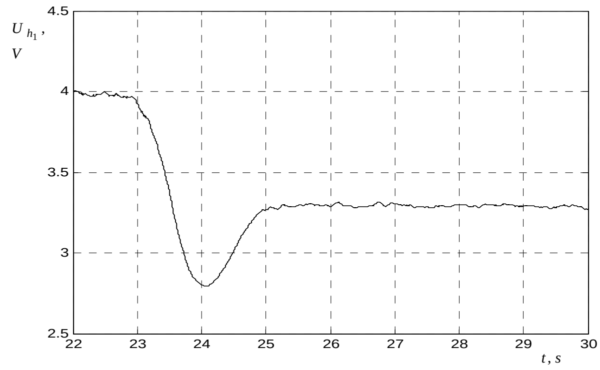

Fig.6a. Pressure of output the pump

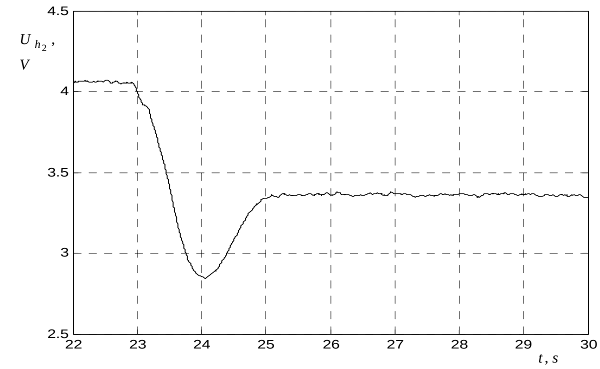

Fig.6b. Pressure of input the turbine

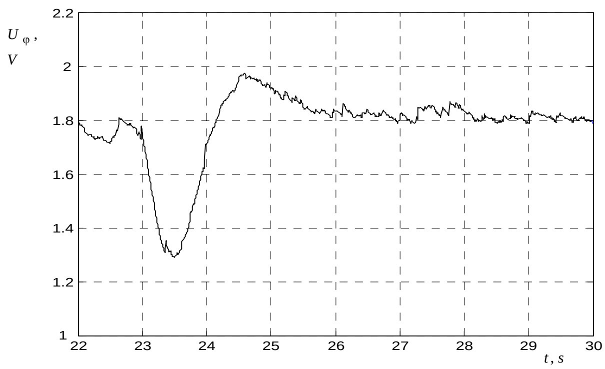

Fig.6c Turnover of the generator

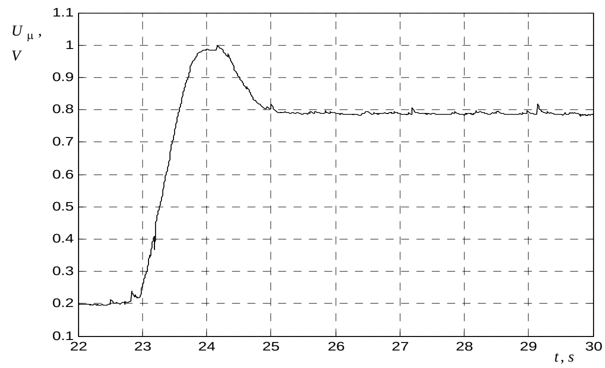

Fig.6d. Position in blade of the water turbine

Fig.6. Processes in the system at 17% loading of the generator

Some investigations with PD and multiparameter controllers have been performed. The results obtained show that with the multiparameter controller the reaction time of the system has been decreased with about 5 % due to the predicted action of the additional feed backs. Some results concerning the dynamical behaviour of the system are shown on Fig. 4,5 and 6.

The water turbine as a control plant is with a big time constant – so the transient processes in the case of load changes of the generator are about 15 s. The pressure pipeline has an indecent influence on the dynamical behaviour of the system due to of the possible of hydraulic-hit. The regulation is strongly influenced by perturbations occuaring in the connection from sensors to controller

IV.CONCLUSION

The developed automated system provides a possibility for studying in real time the dynamical processes flowing in the following pressure system: turbopump-pressure penstock-water turbine. The system is equipped with the required measuring and registrating apparatus. For decreasing of the reaction time structure or/and parameters optimization of the system is needed with an appropriated quality criterion including all sensors information.

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