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ABSTRACT

This Report describes the computerized control system of a 5 MW WWR-SM research reactor. The system is realised as a multilayer decision hierarchy where simple subsystems control the power and the outlet temperature of the reactor under the supervision of a self-organization layer. The structure of the program system and the hardware configuration are presented.

АННОТАЦИЯ

В сообщении описывается система управления с помощью ЭВМ исследовательским ядерным реактором типа ВВР-СМ с тепловой мощностью 5 МВт. Система имеет иерархическую структуру, то есть под управлением самоорганизующейся программы мощностью и выходной температурой реактора управляют простые подсистемы. Описываются построение программ и конфигурация ЭВМ, которыми осуществляются вышеуказанные задачи.

KIVONAT

A Riport ismerteti az 5 MW teljesitményü VVR-SzM kutatóreaktor számitógépes irányitó rendszerét. A rendszer hierarchikus strukturáju program formájában készült el, ahol egy önszervező program felügyelete alatt egyszerü alrendszerek szabályozzák a reaktor teljesitményét és kilépő hőmérsékletét. A program szerkezetét és a megvalósitó hardware konfigurációt egyaránt közöljük.

Introduction

In the middle of the 70's computer control system was decided to be installed in our WWR-SM research reactor to gain some experiences in the field of data acquisition and control systems, and to apply the results of the modern control theory to the control of a nuclear reactor. The open loop data processing stage was achieved at the end of 1976[1]. The control loop was closed in July, 1978. This paper is intended to give an account on the basic concepts of the control and on the technical problems, which have been emerged in the course of the realization. This project was supported by the Hungarian State Office for Technical Development.

Basic Control Concepts

The development of the control system is based on the "low-level safety system" concept, which is motivated by the following objectives:

- to operate the system in an optimal way within the technologically permitted ranges,
- to force the state variables to return into their permitted ranges with a possibly smooth transient.

Such a closed-loop control system can be realized as a functional multilayer decision hierarchy[2], shown in Fig. 1., containing the following strata:

- the selection layer contains a series of subprocess models and the connected performance criteria for the local controls,
- the adaptation layer evaluates the dynamic behaviour of the process and adjusts the parameters of the selection layer so that the models yield a good approximation to the real process,

- the self-organizing layer determines the operational status of the process /i.e. normal, emergency etc./ and on the basis of this decision it selects the relevant models and performance criteria.

The WWR-SM reactor consists of three main constructional units: the nuclear reactor itself, the heat exchangers and the cooling tower. Investigations[2] have shown that the complex reactor model can be partitioned into three loosely coupled subsystems: the nuclear part, the primary and the secondary coolant circuits of the reactor. For technological reasons only two of these subsystems are controlled:

- the reactor power in the nuclear subsystem by means of the reactivity,
- and the reactor outlet temperature in the primary coolant subsystem through the flow rate of the cooling water.

These subsystems are described by the following system equations:

<u>Nuclear section:</u>

$$\frac{dN}{dt} = \frac{\rho - \beta}{\ell^{*}} N + \sum_{i=1}^{6} \lambda_i C_i \qquad /1/$$

$$\frac{dC_i}{dt} = \frac{\beta_i}{\ell^{*}} N - \lambda_i C_i \qquad i = 1 \ldots 6 \qquad /2/$$

$$\rho = \rho_R + \rho_Z - \Gamma_F T_F - \Gamma_R T_R \qquad /3/$$

Primary coolant circuit:

$$K_T N = K_F \frac{dT_F}{dt} + \alpha_F (T_F - T_R) \qquad /4/$$

$$\alpha_F (T_F - T_R) = K_R \frac{dT_R}{dt} + G_P (T_{RO} - T_{RI}) \qquad /5/$$

$$T_R = \frac{1}{2} (T_{RO} + T_{RI}) \qquad /6/$$

$$G_P (T_{PI} - T_{PO}) = K_P \frac{dT_P}{dt} + \alpha_P (T_P - T_S) \qquad /7/$$

$$\alpha_P (T_P - T_S) = K_S \frac{dT_S}{dt} + G_S (T_S - T_{SI}) \qquad /8/$$

$$T_P = \frac{1}{2} (T_{PI} + T_{PO}) \qquad /9/$$

$$T_S = \frac{1}{2} (T_{SI} + T_{SO}) \qquad /10/$$

where symbols N, G, T stand for the number of neutrons, water flow and temperature whereas indices F, R, P, S, I, O mean fuel, reactor, primary circuit, secondary circuit, input and output respectively.

The constant parameters of the above set of equations were identified through measurements of the transient behaviour of the WWR-SM reactor during start-up[2].

As the system parameters are changing in the course of a transient, the adaptation layer fits the parameters of the simple subsystems to the real process. This parameter identification is a fundamental part of the hierarchical control system.

The system equations given above are valid under normal operating conditions, under not too severe disturbances the whole model has to be exchanged. The change of the model is the function of the self-organizing layer. The self-organization is initiated by the alarm analysis[3], which recognizes the disturbance situation by using prestored fault-trees.

The building in of the control algorithms into the computer was preceded by an extensive simulation[5,6] studies which proved the correctness of the control principles.

Realization of the control system

The system is realized by an R-10 process computer using the PROCESS-24K control package[4]. The hardware configuration can be seen in Fig. 2. Since the configuration contains only one CPU, an analogue hardware back-up controller was installed. In the case of a computer failure the control is passed automatically to this back-up, so the operation of the reactor can continue without a break. For this reason, during DDC operation the actual power level is given as power demand to this back-up controller which holds the power level of the reactor at the last correct value if a computer failure occurs. The correct operation of the CPU is checked every second by a simple watch-dog circuit.

The faster nuclear subsystem is controlled every second whereas the slower coolant loop is regulated every 4 seconds. Every control action is carried out by time modulated signals where the time quantum is 50 msec. This type of control is very advantageous because its proper operation can be easily tested. The cycle time of the parameters identification is 15 seconds. In the course of the identification a 3x3 and 4x4 matrices are evaluated.

The biggest problem of the realization was to ensure the desired accuracy of the cycle time in the control of the nuclear subsystem. It was shown by simulation that the accuracy has to be better than ±5%, at last we have achieved ±3%. To gain this result we had to reorganize the queuing method of the disc by introducing suitable task priority system.

Experimental results

At present the compurerized control system operates under the supervision of the classical control room. The value of our control rod is about 1/5 of that of the rod of the old system so it can override our actions at any time. We have examined the behaviour of the DDC system for reactivity disturbances and for transients initiated by the computer operator. The results are in very good accordance with the earlier simulation studies. A measured reactor transient is presented in Fig. 3., where the power was first reduced from 2.5 MW to 1.5 MW, afterwards it was again changed from 1.5 MW to 2.5 MW.

References

[1] J. Péter, E. Végh: Data Acquisition Program for a Nuclear Research Reactor. 2nd International Conference on Centralised Control Systems. IEE Publ. No. 161. pp. 131-134. 1978. London.

[2] E. Zobor et al.: Computer Control System Synthesis for Nuclear Power Plants ... IAEA Progress Report No. 1194/RB. 1973.

[3] L. Bürger, E. Zobor: On-line Alarm Analysis of the WWR-SM Research Reactor. International Symposium on Nuclear Power Plant Control and Instrumentation. IAEA - SM 226/17. 1978. Cannes.

[4] L. Bürger, E. Végh, et al.: PROCESS-24K an Efficient Process Control System. Report KFKI-1978-17.

[5] E. Zobor et al.: Computer Control System for Nuclear Power Plants ... Final Report of the IAEA Research Contract No. 1194/RB. 1978. Report KFKI-1980-58.

[6] Á. Szentgáli: Direct Digital Power Controller for a Research Reactor. Kernenergie. Jan. 1980. pp 93-96.

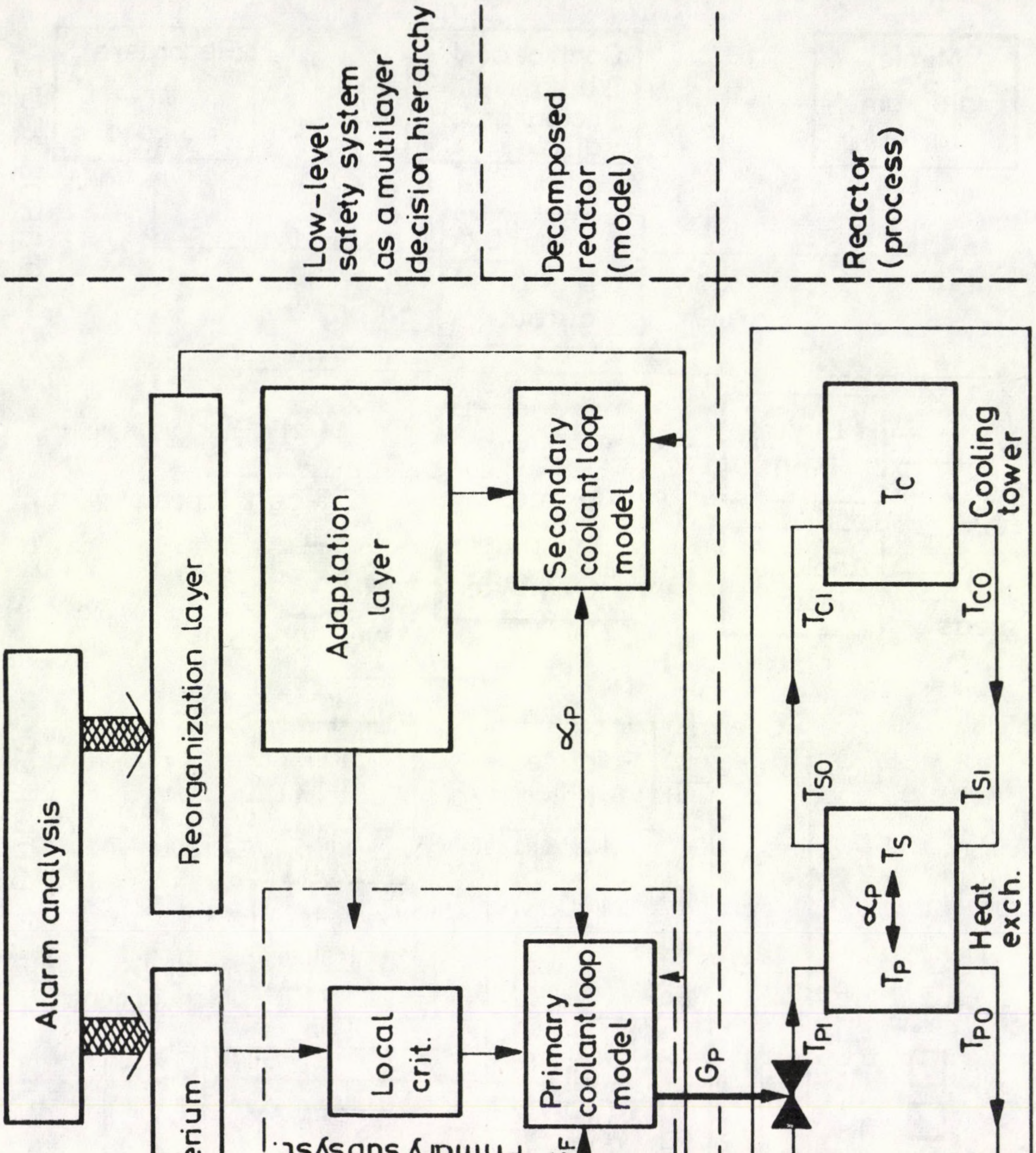

Fig. 1.
Functional structure of the program

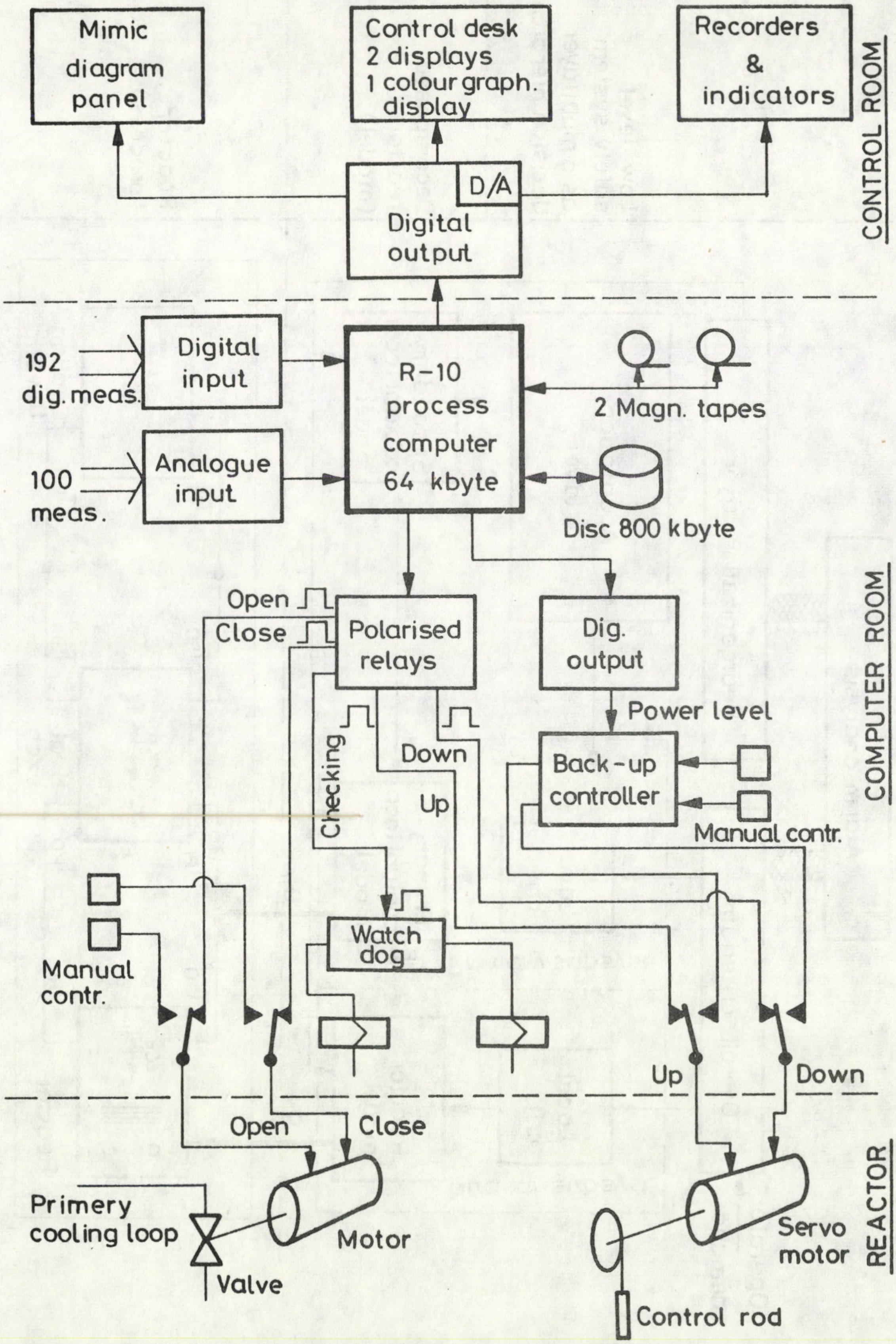

Fig. 2.

Hardware layout of the system

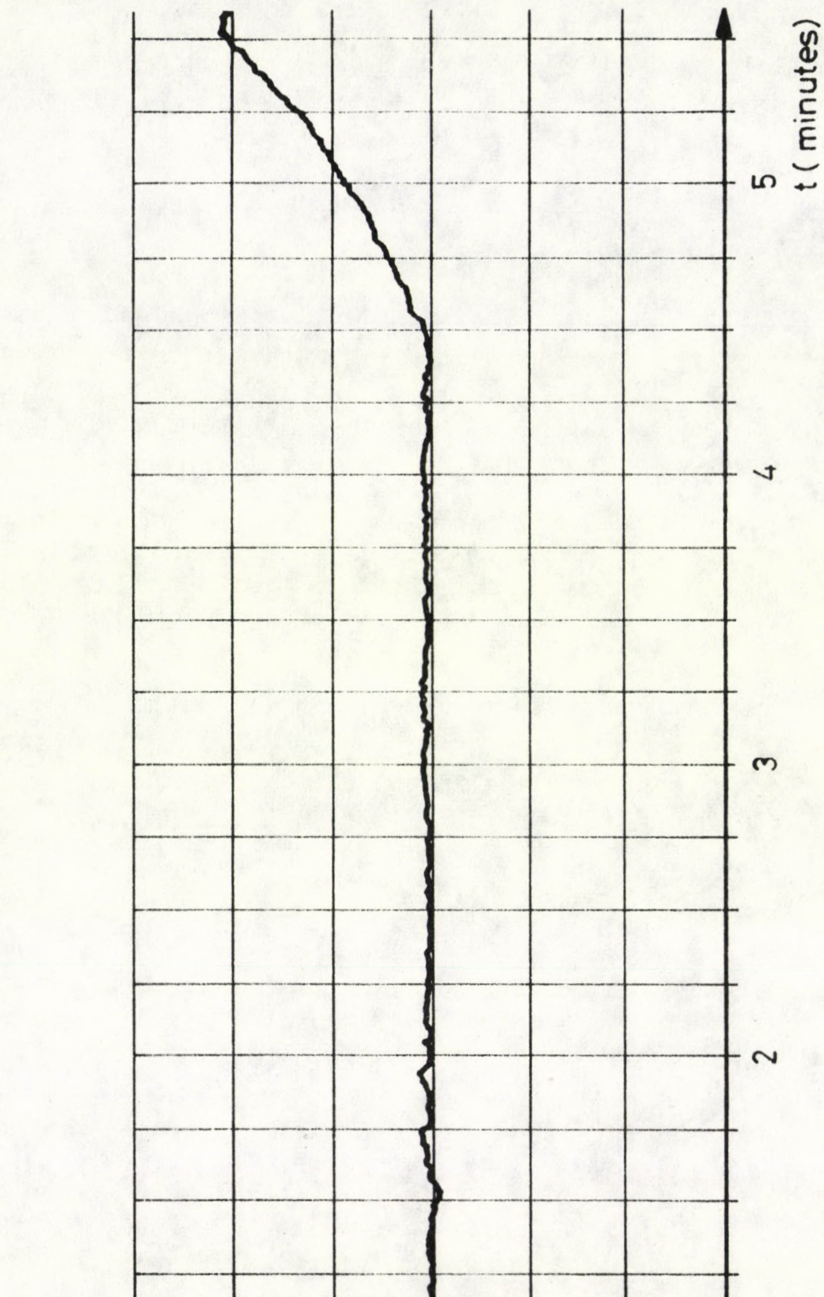

Fig. 3.
Controlled reactor transient

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