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COMPUTERIZED REACTOR MONITOR AND CONTROL FOR RESEARCH REACTORS

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ABSTRACT

The computerized process control system, built in the Central Research Institute for Physics, Budapest, Hungary, in general, and its special applications at research reactors are described in this paper in a short from. The nuclear power of the Hungarian research reactor is controlled by this computerized system too, while in Libya many interesting reactor-physical calculations are built into the computerized monitor system.

АННОТАЦИЯ

Сообщение описывает в главных чертах разработанную в Центральном институте физических исследований систему управления производственными процессами с применением ЭВМ, и некоторые применения ее при исследовательских ядерных реакторах. Система управления с ЭВМ Будапештского реактора выполняет задачу регулирования мощности. Информационно-вычислительная система Ливийского реактора содержит ряд интересных реакторно-физических расчетов.

KIVONAT

Az előadás röviden ismerteti a Központi Fizikai Kutató Intézetben készült számitógépes folyamatirányitó rendszert általában, valamint annak speciális alkalmazásait kutató reaktoroknál. A budapesti kutatóreaktorban a teljesitményszabályozás is e rendszerrel történik. A libiai kutatóreaktornál felépült monitorozó rendszer viszont számos, érdekes reaktorfizikai számitást tartalmaz.

1. INTRODUCTION

The need to renew the obsolescent instrumentation of our more than 20-years-old research reactor induced the development of a computerized reactor monitor and control system in the middle 1970s. The execution was so successfully performed that it is already applied not only in controlling the research reactor of the Central Research Institute for Physics, Budapest, but also for monitoring a research reactor now being established in Libya. Judging by its capacity it is suitable for application in a nuclear power plant as well.

2. GENERAL DESCRIPTION

The main part of the system is the R-10 computer /VIDEOTON, Hungary/ based on the French MITRA-15 (*Fig. 1.*). The back-up memory is a disc with 850 kbyte capacity. The magnetic tape unit serves for data archivation. Slow, integrating type A/D converters /max. 4, each capable of 30 meas./sec/ are among the interfaced real-time peripherals. Some 2000 analogue input channels and about 2000 bits binary input and the same number of output signals can be connected to the system. The throughput of the max. information rate requires about 72% of the CPU time. Displays and logging peripherals serve for man-machine interaction. All the elements of the configuration are Hungarian made apart from Bulgarian magnetic tape units.

A very flexible software system is built into this hardware, its name is PROCESS-24K [1]. Its structure can be considered as an arrangement in four layers (see *Fig. 2.*)

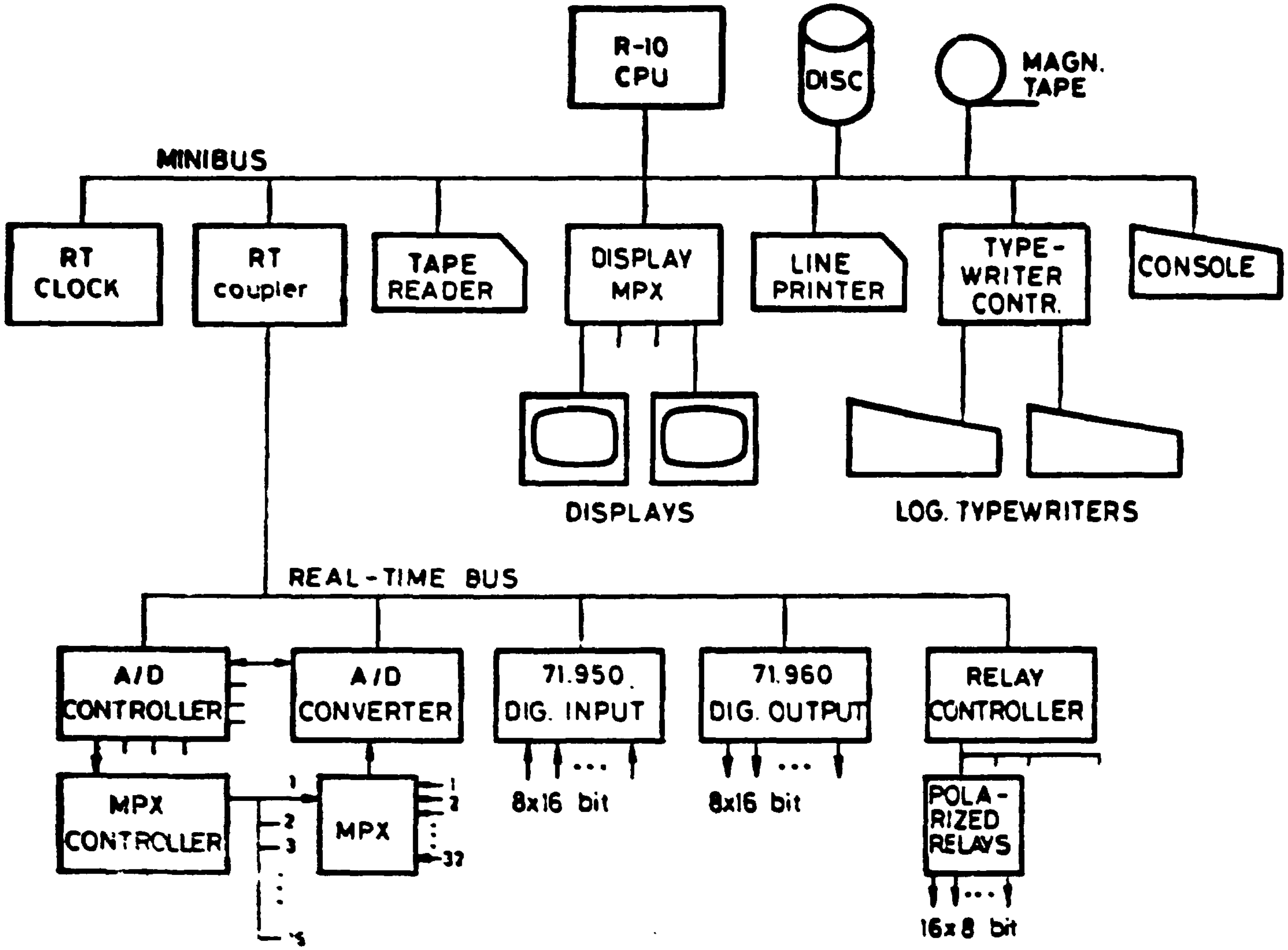

Fig. 1
Hardware configuration.

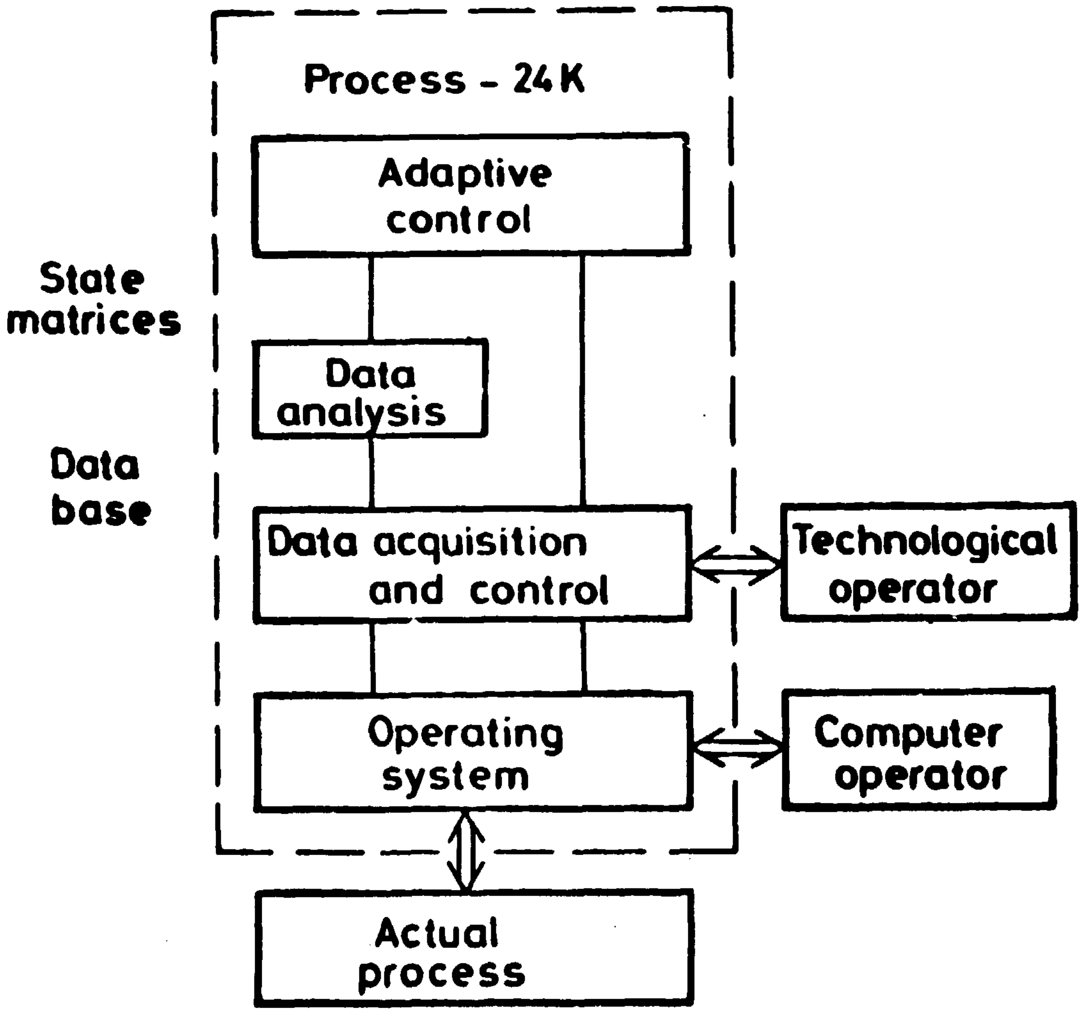

Fig. 2.

Software structure.

- operating layer, consisting of the monitor modules, peripheral handlers, swapping control, background organization, buffer system, error recovery procedures and the computer-operator interface;
- data acquisition and control layer, containing timing, measurement organization, primary data processing/ scaling, validity checking, filtering, etc./, data

base organization, control algorithms, data logging and technological operator interface;
- data analysis layer, representing trend analysis, alarm analysis, description of alarm trees, alarm presentation;
- adaptive control and optimization layer, representing tasks concerned with providing new configurations for the actual data acquisition and control layer.

These layers are built on each other hierarchically. In general there are connections only between the neighbouring layers; for this reason every layer has its specific interface system. Every layer has special dependence on the actual process and it is weaker in the lower layers than in the upper ones. While for example the operating layer does not depend on the actual process and is determined by the central processor and its peripherals the adaptive control layer is defined mostly by the controlled process and is not connected very closely with the computing hardware.

From an information processing point of view this system provides two images of the outer world /i.e. the controlled process/. The data acquisition layer updates cyclically a data base which is a more or less unstructured picture of the process containing every measured item of information without any deduction /except for validity checking/. The data analysis layer generates a structured picture of the process so this image depends not only on the measured quantities but on the ordering principle too. Consequently this picture is more abstract and condensed than the former one; at this level the process is described by state matrices.

PROCESS-24K, being a general real-time system, contains only the process independent part of the control system and all of the software aids by which a specific installation can be constructed; for this reason the lower layers are much richer and polished than the upper ones.

The main software aid is the higher level language, named PROCESS. It is used for programming the real-time tasks. These programs are compiled and linked in the background of the system and they can immediately be loaded with the other real-time tasks enabling enlargement of the measuring system to be carried out during actual operation. Various instructions are in this language: from the instructions of the primary data processing /linearization, filtering, limit checks, etc./ to the sophisticated actions of the vector and matrix arithmetic.

3. APPLICATIONS IN RESEARCH REACTORS

The main aspects relating to the development of the control system in the research reactor in Budapest were the following:

- to build a new control room with an improved, better organized man-machine communication,
- to work out some methods of secondary data processing: alarm analysis, trend analysis [2,3],
- to test in practice the theoretical results gained from the control theory investigations in our Institute, to solve the computerized control of th reactor power [4,5].

There was no claim to power control in the case of the Libyan reactor, bit a series of reactor-physical calculations and some special functions supporting the operating staff were needed. These will be described here.

3.1. Man-machine communication

Two CRT displays, one for communication with the operator, the other for alarm presentation, are built into the control desk.

The measured values and the data of their primary processing /alarm and validity limits, constants of linearization, etc./ may be requested and partly modified through the operator's display. Various technological logs, containing different groups of data /e.g. data of reactor zone, data necessary to start up, etc./ are presented as well.

In particular, many different technological logs are built into the Libyan system. Here more than 35 logs are selectable on a functional keyboard. The chosen log is presented on the CRT and its values are updated every 15 sec. A number of reactor-physical parameters, spatial distributions of several data of zone /power distribution, thermal and fast neutron flux, actual uranium content of the zone, etc./ are arranged into a suitable, easy to survey form on these pictures.

The list of the actual alarms is presented on the alarm display; these alarms are accompained by a light and sound signal until the operator's acknowledgement.

A hardcopy is made about the alarms and about all the modifications concerning the data measurement and processing /e.g. alarm limit values/ in the event log.

The control desk contains several digital displays too, where the measured values of variables, selected by thumbwheel switches, are presented and updated every second.

An operation log containing the values of the most important data is made hourly but it can be made at any time.

The values of a maximum of 48 variables are stored in a post-mortem log on the disc, with 4 sec time resolution. The operator may request the list of these values, using the "post-mortem" key, e.g. in disturbance cases. Then the data collection will continue further for 8 minutes and the post mortem list will contain the data of ±8 minutes before and after the using of the key.

3.2. Secondary data processing methods

Two methods have been elaborated for further processing of the primary data base, these are:

- trend analysis,
- alarm analysis.

The alarm analysis is installed in the Budapest system only.

3.2.1. Trend analysis

The presentation of trend data is different for the two research reactors. The alphanumeric display for the alarm lists was used in the Libyan system, so the form of trend data presentation is the histogram (*Fig. 3.*). A special hardware device, the four channel curve-plotting option of a colour quasi-graphic display is used for the same purpose at the reactor in Budapest (*Fig. 4.*). The advantage of the first solution is that dates and measured values are very exactly shown on the picture, but only a few data can be presented at a time. The whole content of data storage can be seen on the CRT in the case of the second solution, but only approximative dates and values can be read from it.

Only the methods of presentation are different: data collection is similar for both systems: measured values of max. 48 variables, collected during a short /e.g. 1 hour/, a middle and a longer /1-2 days/ period are stored in a cyclical organized buffer on the disc. The time resolution varies from 4 sec, to 0.5 hour. Data of a one-day period /time resolution 30 min/ are archived to magnetic tape automatically at midnight, but the operator can initiate archivation at any time. After reading back the archived data from the tape, they can be presented on the CRT as well.

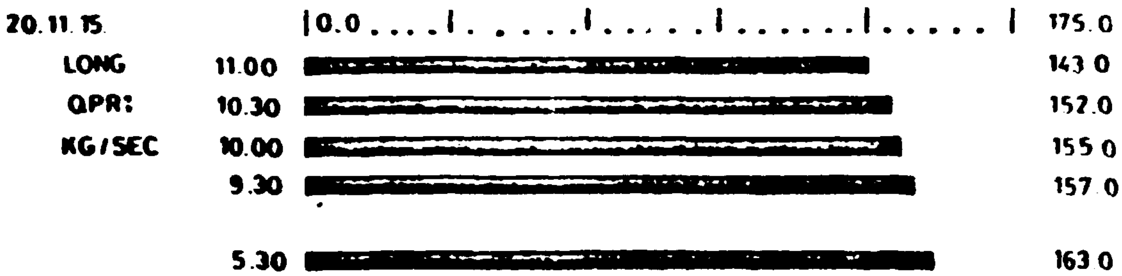

Fig. 3.

Presentation of trends on alphanumeric display.

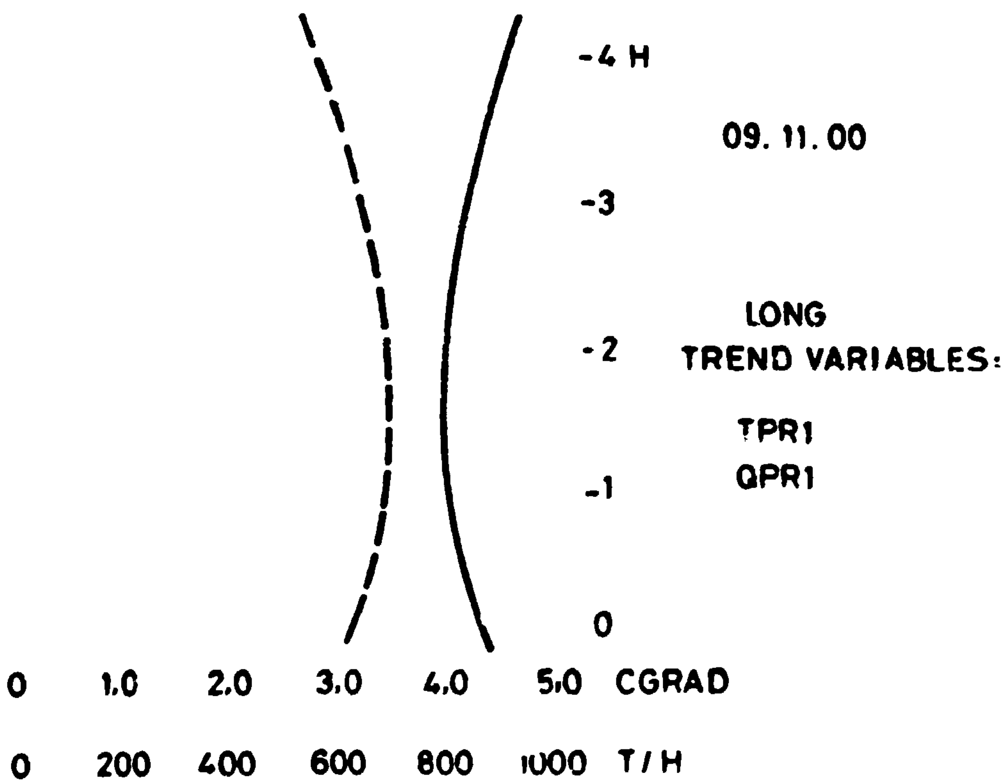

Fig. 4.

Presentation of trends on quasi-graphic display.

3.2.2. Alarm analysis

Alarm analysis supports the operator mainly in the most critical, disturbance cases [5]. It uses the fact that the "pattern" of the alarms, occuring at approximately the same time, may characterize the cause of the disturbance. The logical connections between the alarms and disturbances are analysed in advance, and the results are stored in the alarm library of the system in the form of binary trees /alarm trees/. In the case of a new alarm signal the analysis program tries to fit it to the stored trees. If all the logical conditions are satisfied, it means that the analysis reaches the top event on the tree, the operator gets a text on the alarm display concerning the cause of the disturbance. We analyse only the causes, not the consequences. The alarm trees stored in the system are smaller and simpler than the usual fault trees of disturbance analysis. The reason for this is partly the required speed of the real-time analysis, partly that the research reactor is rather small and simple. If the operator desires to survey the logical connections, he can see the whole alarm tree on the CRT.

3.3. Computerized reactor power control

Investigations in the field of control theory carried out in our department were tested at the research reactor in Budapest. An adaptive, hierarchically structured control method is built into the computerized system [5,6] (Fig. [illegible].). The simplified reactor model is divided into loosely coupled subsystems /nuclear, primary, secondary subsystems/, each has its own optimization criteria and is controlled separately. These form the "selection" layer. 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, on the

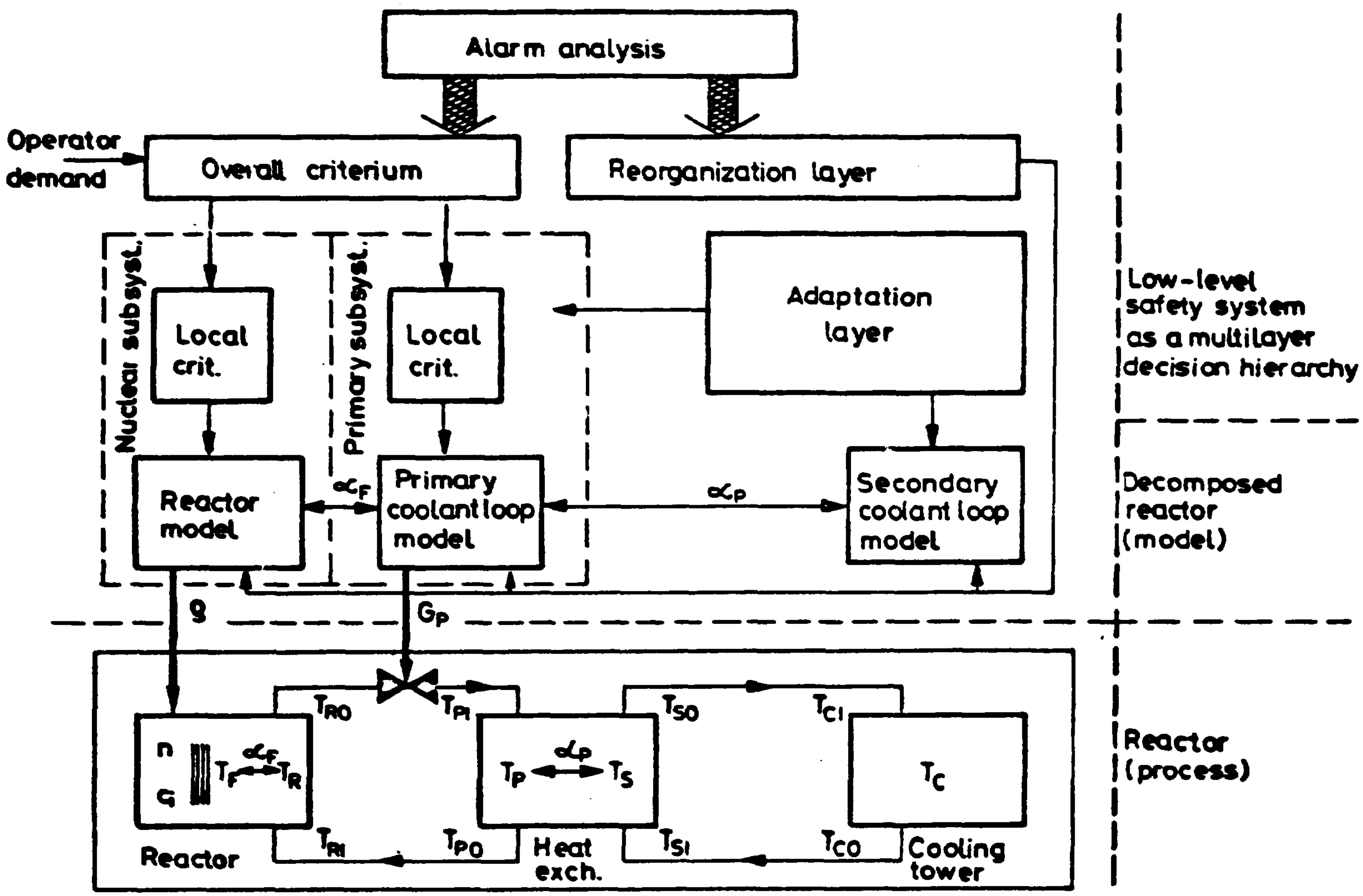

Fig. 5. Structure of reactor control

upper level of the hierarchy, takes into account the signals of the alarm analysis and determines the operational status of the process /i.e. normal, emergency, etc./ and on the basis of the decision it selects the relevant model and control algorithm.

Maximum safety was the first aim during the realization. The control is switched over backup hardware in case of computer failure. The safety system works independently from the computer.

3.4. Reactor-physical calculations and additional operation functions

A series of reactor-physical calculations are built into the Libyan research reactor system. The zone of this reactor is quite well instrumented so it is possible to calculate the spatial distribution of such parameters, such as the thermal and fast neutron flux and the nuclear power. The distribution of the thermal flux is calculated along the Z axis, then the most heated fuel element is selected and the temperature distribution is defined along it. The departure to nuclear boiling factor /DNB factor/ is defined at the hottest spot of the most heated element.

An exact register is kept about the actual uranium content of the fuel elements, and the in-core detectors are calibrated daily.

The operating staff is supported by the computer when executing some special operational functions as well. These are the following:

- reloading of the zone,
- rod calibration.

The initial and actual uranium content of the fuel elements, the integrated fast and thermic neutron flux are registered at reloading. The most important data of the in-core detectors and the control rods are stored too. All these data are printed out and stored on magnetic tape for further processing on a larger computer.

The rod to be calibrated can be moved and the efficiency can be calculated in a maximum of 60 steps in the course of the calibration operating mode. The differential reactivity is calculated at each step and the integral reactivity is presented to the operator at the end of this procedure.

4. FURTHER DEVELOPMENTS

Our plans relate to increasing the reliability of the system. The first step, which is virtually ready, is the building of a dual processor system. In case of a processor failure, the other takes over its tasks, and with the exception of some supplementary services /e.g. trend analysis/, the provisions of the system are further available.

The next step will be a distributed intelligence system, where the measuring and primary data processing tasks are in the local microcomputers and only the more sophisticated calculations and the information presentation in the control room are in the central dual processor. These plans already surpass the research reactor project, they go towards applications in nuclear power plants.

5. ACKNOWLEDGEMENTS

The project described above was the work of a team of about ten members. We should like to express our thanks tc all of them. We are especially grateful to E. Zobor for his control theory investigations, and to J.S. Jánosy for his reactor-physical expertise; these were essential to the accomplishment of this task.

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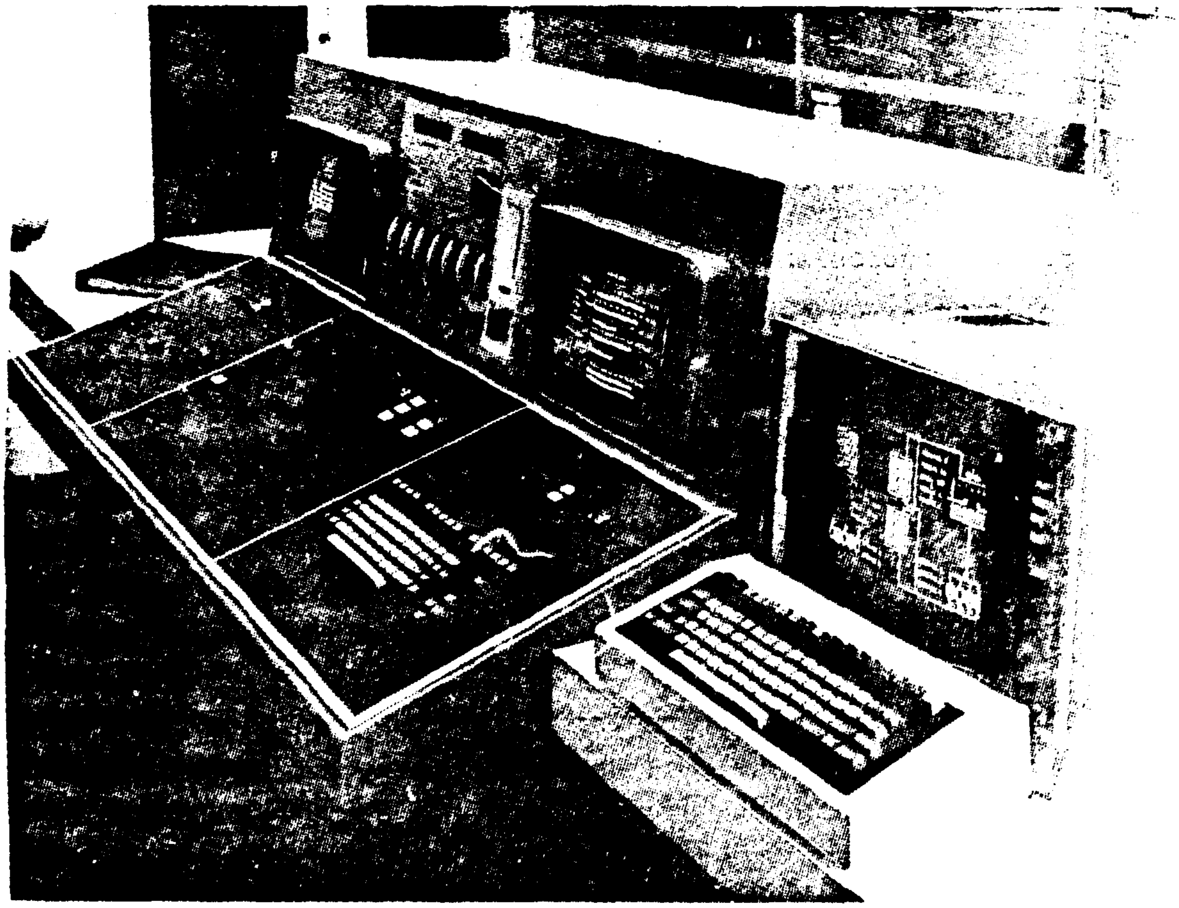

Fig. 6.

Control room of the Hungarian Research Reactor, Budapest

Kiadja a Központi Fizikai Kutató Intézet
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Szakmai lektor: Jánosy János Sebestyén
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Budapest, 1981. szeptember hó