A TECHNICAL SYSTEM TO IMPROVE THE OPERATIONAL MONITORING OF THE ZAPOROZHYE NUCLEAR POWER PLANT

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1. INTRODUCTION

As part of the programme implemented by the German Ministry of Environment, Nature Conservation and Reactor Safety to cooperate with the CENTRAL AND EASTERN EUROPEAN STATES and the COMMONWEALTH OF INDEPENDENT STATES in the area of nuclear safety, a technical system to improve operational monitoring has been designed [1], specified [2] and established [3] since 1992 as a pilot project in the Zaporozhÿe/Ukraine[1] nuclear power plant by RESEARCH CENTRE ROSSENDORF and TECHNISCHER ÜBERWACHUNGSVEREIN RHEINLAND with a significant contribution from the State Scientific and Technical Centre of the Ukrainian supervisory authority.

The technical system complements existing operational checking and monitoring facilities by including modern means of information technology. It enables concentration on a continuous monitoring of the state of unit 5 in normal operation and in cases of anomalies or incidents so that when recognisable deviations from the regular plant operation occur, the Ukrainian supervisory authority can immediately inquire and if necessary impose conditions on the operator. The radiological and meteorological parameters at the nuclear power plant location are monitored to the extent necessary to assess the current radiation situation and to implement effective emergency management measures.

2. SELECTION OF PARAMETERS FOR MONITORING

The parameters to be monitored were selected on the basis of German and international experience using the criterion of being able to observe and evaluate the adherence to the following four protection aims

- P1 Assurance of reactor shutdown
- P2 Assurance of core cooling
- P3 Assurance of heat removal from the primary circuit and assurance of its integrity
- P4 Assurance of the integrity of the containment

in connection with nine monitoring tasks which refer to certain parts of the plant, mediums, processes and plant conditions.

These monitoring tasks are related to:

- M1 General plant condition
- M2 Barrier effectiveness
- M3 Radioactivity inventories
- M4 Release of radioactive substances into the air

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[1] The Zaporozh'ye nuclear power plant is located about 500 km south east of Kiev on the southern bank of the Dnieper River, which is dammed-up to the Kachovska storage lake. It has six uniform units of the type VVER-1000/V-320. With an electric output of 6,000 MW this nuclear power plant is the largest nuclear power generator in Europe at present.

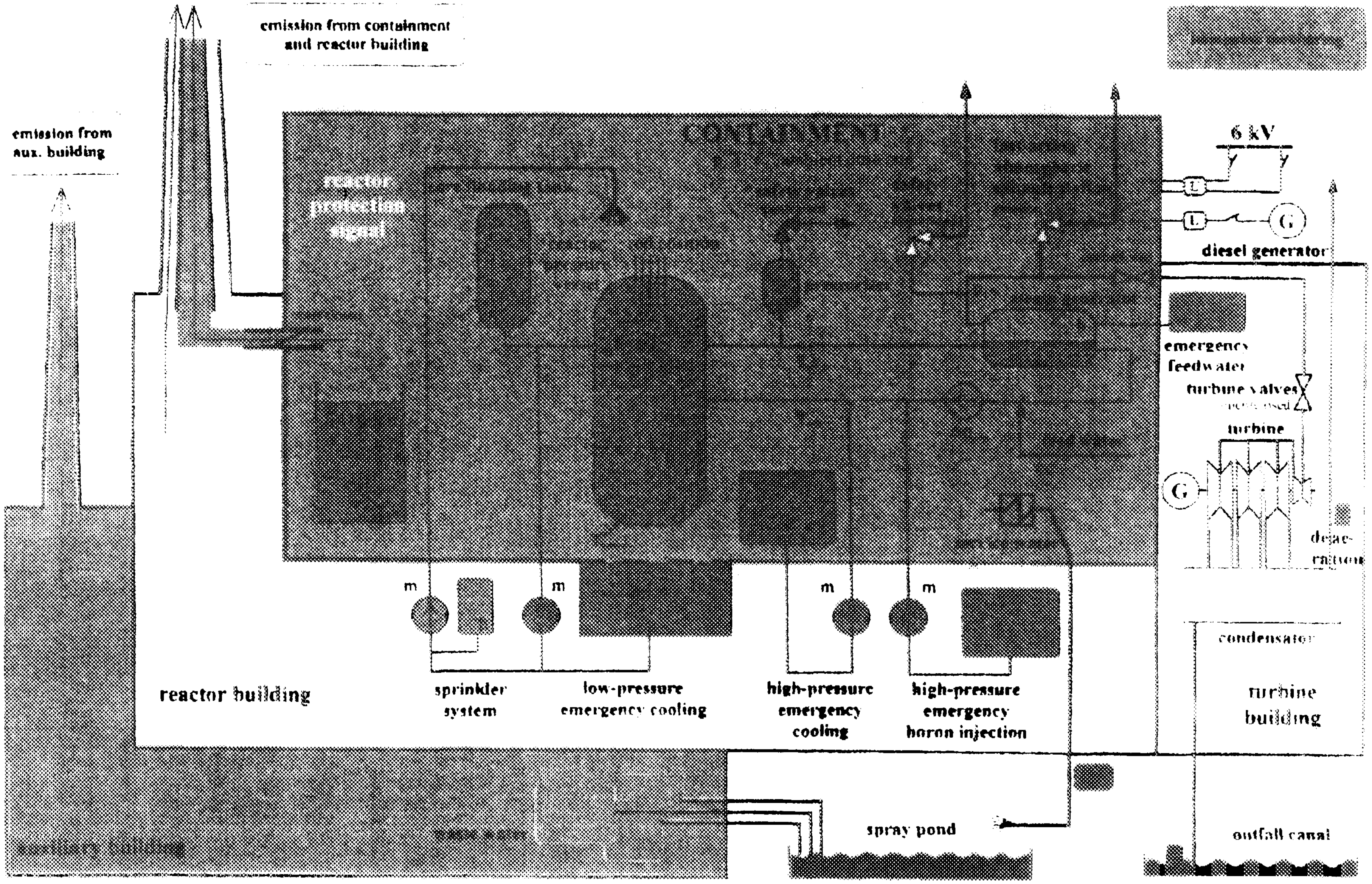

Figure 1 Parameters selected for the operational monitoring and their assignment to systems and components

M5 Immissions into buildings and surroundings
M6 Registration of the meteorological conditions
M7 Release of radioactive substances into water
M8 Adherence to monitoring-specific threshold values
M9 Plant condition in the event of anomaly or incident/accident.

While the protection aims for the various pressurised water reactor types may be generally valid, the monitoring tasks are specifically tailored to the Zaporozh'ye nuclear power plant.

The advantage of these procedures is that monitoring the protection aims in connection with control tasks is self-redundant and complements the monitoring of the limit values and conditions of safe operation which the operator has to carry out in accordance with the operating instructions.

On the basis of the protection aims and monitoring tasks concept
49 different safety related operational parameters of the core and unit
18 radiological parameters of the unit and the plant site and
6 meteorological parameters
are permanently and automatically recorded, monitored and evaluated.

Fig. 1 shows schematically the parameters which are selected for monitoring. The colors in the figure characterises different parts of the unit and the plant. The colors approximately marks the monitoring tasks but not the protection aims. For example the parameters indicated in the red-marked pressure vessel characterise the states of the nuclear process and of the primary circuit (part of the general plant condition M1). Additionally, they enable to observe the assurance of three protection aims: reactor shutdown (P1), core cooling (P2) and heat removal (part of P3). This fact points out the complexity of the monitoring procedures: The actual values of the single parameters are compared for various monitoring tasks with limit values which possibly depend on the task itself. After that the results of the comparison are combined to form logical information which makes it possible finally to conclude whether the protection aims are assured or not.

3. AUTOMATIC EVALUATION AT THE NPP SITE

The technical system set up in the Zaporozh'ye nuclear power plant is hierarchically structured (fig. 2). The system is realised by a site-wide local area network LAN connecting all six reactor units, two auxiliary buildings, the laboratory building and the so-called ZAPOROZHÝE CENTRE in the form of a sheltered room. The on-site radiological and meteorological parameters are collected in the operational computer of the auxiliary building #2. From that this parameters are down-loaded by the TRANSFER COMPUTER AUXILIARY BUILDING #2 and the operational parameters of the monitored unit #5 are down-loaded by the TRANSFER COMPUTER UNIT #5 every four seconds. There they are checked and condensed individually or in monitoring-specific links to representative logical data channels and transferred as data packages at time intervals of one minute to the SERVER and to the ON-SITE COMPUTER in the laboratory building. The steps of data handling and processing as well as the realised distribution of this steps onto the different computers at the Zaporozh'ye NPP site are shown in the table 1.

In the ON-SITE COMPUTER the process and plant status is finally evaluated by comparing the current data with monitoring-specific limit values and by combining the limit value violation of different parameters [4]. The monitoring-specific limit values generally lie above the operational tolerance values to prevent any restrictions of the operator's room for manoeuvre but necessarily lie below the approved limit values set by the authorities and below the load limit values specified by the manufacturers, respectively.

If no violation of the protection aims is found, the users receive a data file every 10 minutes, only. Excess of threshold values causes a report to be sent to the users in the Zaporozhýe Centre (authority) and in the administration building (On-site-inspector and operator). In view of the importance and possible effects of excess, there are three different information levels called NOTICE ☐, WARNING ☎ and ALARM 🔔.

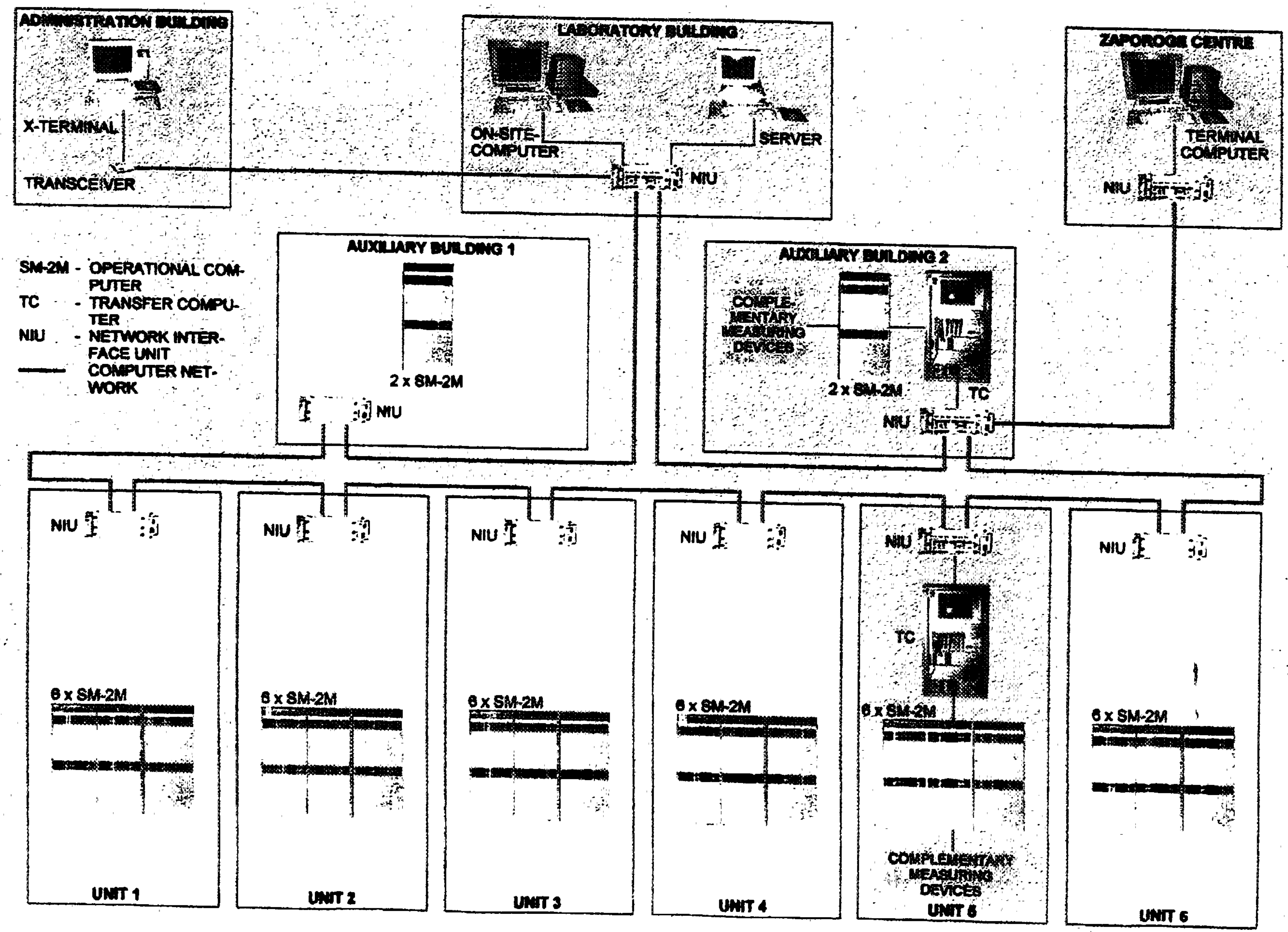

Figure 2 The structure of the technical system at Zaporozhýe NPP site to improve the operational monitoring

Computer type	Location at the NPP	Functions
TRANSFER COMPUTER (VME-BUS Computer)	Reactor unit and auxiliary building	• down-loading of the primary data coming from the operational computer, input check • selection of data to be monitored • conversion into measuring-channels • plausibility and confidence checks • conversion into temporary data channels • summarising and conversion into representative logical data channels, trend estimation
SERVER (SUN SPARC-station 20)	Laboratory building	• general information and data handling
ON-SITE COMPUTER (SUN SPARC-station 5)	Laboratory building	• evaluation of the logical data channels by means of monitoring-specific threshold values • summarising the evaluation results • information supply for the users • general system and state control • information storage and back-up
X-TERMINAL (SUN SPARCclassic)	Administration building	• visualisation and utilisation of all information of the technical system by the ON-SITE-INSPECTOR of the supervisory body
TERMINAL COMPUTER (SUN SPARC-station 20)	ZAPOROZHYE CENTRE (sheltered room)	• visualisation and utilisation of all information of the technical system by the supervisory authority at the operator, • data processing and data transfer to the KIEV CENTRE of the supervisory authority (next step of extension)

Table 1: Computers and their functions

- A Notice ☐ is sent to the authority and the operator in the event of a failure in redundant measuring lines or safety systems if it reduces safety margins. The report consists of a short verbal communication on display and logging printer, the indication of the failed measuring channel or system and the repair deadline which must be complied with. The notice is automatically cancelled when the cause has been eliminated.
- A Warning ☎ is conveyed to the users in the event of a violation of at least one protection aim. It consists of verbal communication and announcement on the display, entry in a warning journal and the output of actual values and limit values of the monitored parameters which can be linked to the protection aim violation. This information should give the trained specialist an overview of the process and plant status which emerged. The receipt of warning must be acknowledged by the users. A state of warning may only be cancelled when the authority gives its consent and no further protection aim violation has occurred for a fairly long period.
- An Alarm 🔔 in the technical system is triggered if in case of a protection aim violation a process or plant status is reached which for safety reasons requires intensified monitoring. This is always necessary when incidents or accidents occur such as in the International Nuclear Event Scale INES for significant events in nuclear engineering installations. Whereas in all states from normal operation to warning the operational information is transmitted to the users at time intervals of ten minutes and the radiological-meteorological data of sixty minutes, in the state of Alarm the intervals between two consecutive transmissions are shortened to one and ten minutes, respectively. Moreover, the conditions of the Warning state are valid, too.

Due to the above-mentioned different information levels the algorithms for the automatic evaluation are very complex. Additionally, the algorithms use different threshold values for diffe-

condition of FTL	crossing threshold			algorithm producing different NOTICES if the actual representiv value undercrosses or overcrosses the threshold values
	① ⇔ ②	② ⇔ ③	① ⇔ ③	
NORMAL FTL > ltv1 AND NOT EQU ERROR	① ①		① ①	①⇨② [(FTL(t)<ltv1) AND (FTL(t)>ltv2 AND NOT EQU ERROR) AND (FTL(t-1minute)>ltv1 AND NOT EQU ERROR)] EQU L; *output string:* ***tank level LOW;*** ①⇦② [(FTL(t) > ltv1 AND NOT EQU ERROR) AND (FTL(t-1minute) < ltv1 AND NOT EQU ERROR) AND (FTL(t-1minute)>ltv2)] EQU L; *output string:* ***tank level NORMAL;***
ltv1				
FTL < ltv1 AND NOT EQU ERROR AND FTL > ltv2 LOW	□ ② ②	② ② □	□	②⇨③ [(FTL(t) < ltv2 OR EQU ERROR) AND (FTL(t-1minute) > ltv2 AND NOT EQU ERROR) AND (FTL(t-1minute) < ltv1)] EQU L; ***tank level INSUFFICIENT;*** ②⇦③ [(FTL(t) > ltv2 and NOT EQU ERROR) AND (FTL(t) < ltv1) AND (FTL(t-1minute) < ltv2 OR EQU ERROR)] EQU L; *output string:* ***tank level LOW AGAIN;***
ltv2				
FTL< ltv2 OR EQU ERROR INSUFFICIENT		③ ③	③ ③	①⇨③ [(FTL(t) < ltv2 OR EQU ERROR) AND (FTL(t-1minute) > ltv1 AND NOT EQU ERROR)] EQU L; *output string:* ***tank level INSUFFICIENT;*** ①⇦③ [(FTL(t) < ltv1 AND NOT EQU ERROR) AND (FTL(t-1minute) < ltv2 OR EQU ERROR)] EQU L; *output string:* ***tank level NORMAL;***

Figure 3 Example of an algorithm of the automatic evaluation of the parameter „emergency core flooding tank level" (FTL), using two different threshold values ltv1 and ltv2 for minimum water level

A NOTICE □ is given to the users, if the actual value of the parameter FTL crosses the monitoring-specific threshold values ltv1 or ltv2, independently of its positive or negative trend. Because of the safety relevance of this parameter an information channel failure (ERROR) will be evaluated like undercrossing the lowest threshold ltv2.

Remark: The parameter FTL becomes important if the emergency core cooling systems are in operation. In this case the information level ALARM already exists. Therefore the evaluation leads in a NOTICE stage □ only to reduce the displayed, printed and stored information, respectively.

rent purposes to detect limit value violation and they derive different conclusions from the fact of threshold crosses of different parameters. Additionally, the algorithms based on the actual values of selected parameters and their threshold violations have to be compared with the values one minute before to update the evaluation result as shown exemplary for the parameter „emergency core flooding tank level" FTL in fig. 3. Figures of this kind are used to develop the evaluation algorithms.

4. STATE OF THE SYSTEM

Test operation of the technical system to improve operational monitoring was commenced at the end of 1995. Since then, on-site supervisory authority and operator have been able to fulfil their monitoring duties more efficiently than before, based on the automatic evaluation and on presentations of actual parameters as shown in fig. 4 for the operational parameters for example.

After the completion of the user software by the State Scientific and Technical Centre of the Ukrainian supervisory authority and the operator, which the German partners assisted by consulting, and after having proven the reliability of the system under nuclear power plant conditions the industrial testing phase of the system has been started in the middle of 1996. In 1997 the technical system will be connected to the KIEV CENTRE of the Ukrainian supervisory authority.

The described technical system is unique in terms of its effective monitoring of nuclear power plants with VVER-1000 reactors in the Central and Eastern European states and in the CIS. The modular and open structure of the system makes it possible to extend the monitoring to all six units at the Zaporozhýe NPP and to connect more users.

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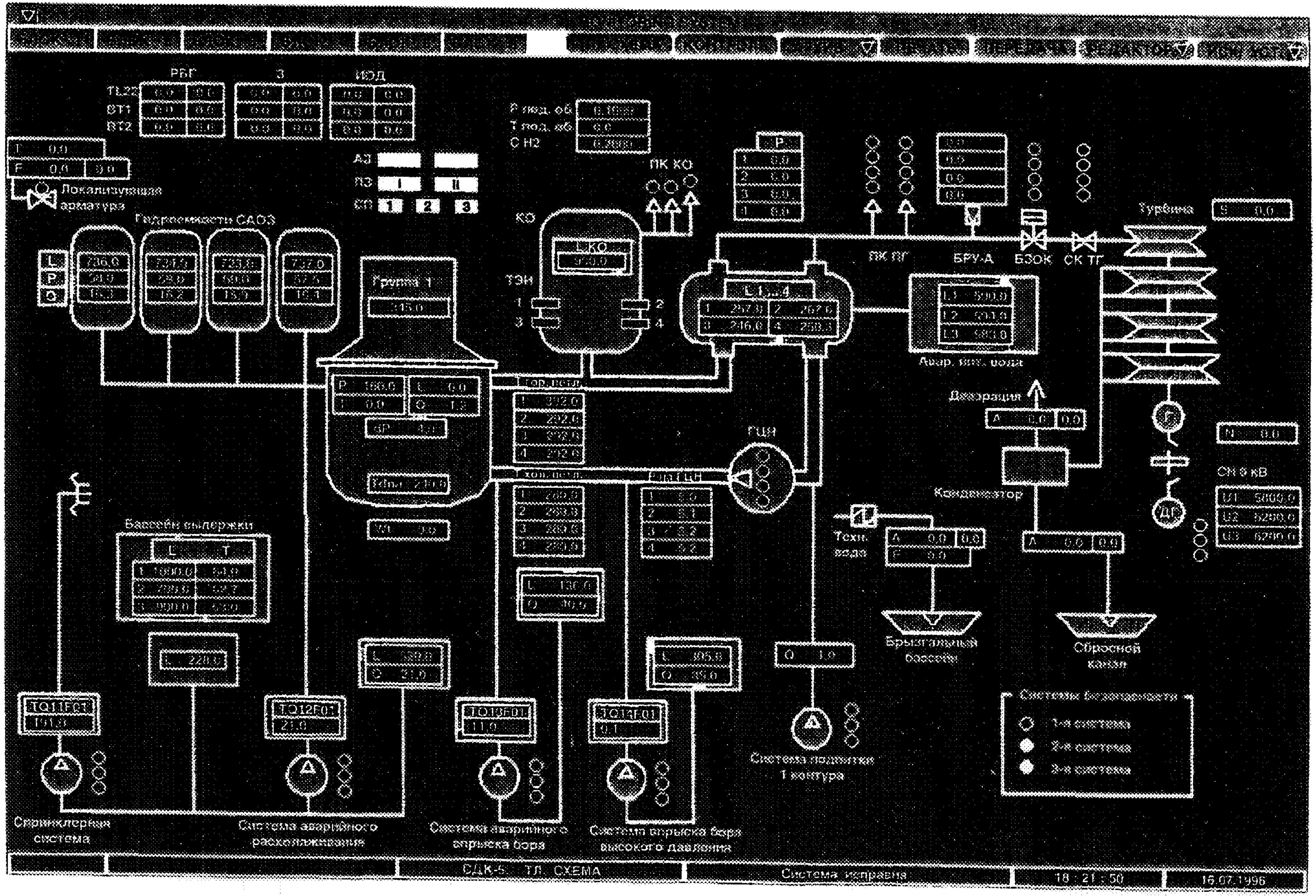

Figure 4 Technological sheme for the representation of the actual operational parameters at the 5-th unit of Zaporozhýe NPP