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ФИЗИКА И ТЕХНИКА УСКОРИТЕЛЕЙ

HOST-BASED DATA ACQUISITION SYSTEM TO CONTROL PULSED FACILITIES OF THE ACCELERATOR

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The report discusses development of the host-based system to carry out timed measurements and data acquisition for the control of pulsed facilities of the accelerator. We consider modes of timing and allocation of operations of channels and the system node. The time of any working cycle of the pulsed facilities, rate of a data flow and an amount of serviced channels are coordinated with operation characteristics of the system node. Estimations of the readout rate of the data and the waiting time demonstrate the system efficiency. The technique has been developed to provide checking of groups of pulse parameters and control the facilities of the linear accelerator of electrons LUE-200 of the neutron source IREN.

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INTRODUCTION

The system of synchronized data acquisition has been developed to control pulsed facilities of the linear accelerator of electrons LUE-200 of the neutron source IREN [1]. A multiplex system of data acquisition for monitoring the working cycle parameters (its time period T, from one pulse of the electron beam up to another one, and repetition rate $-1/T \leqslant 150\ \mathrm{s}^{-1}$) was offered and tested while the full-scale test facility of IREN was equipped with the instruments. Timed procedures of techniques of data acquisition [2] are applied further in the host-based solutions to a group of tasks to supervise process variables and control pulsed facilities. The advanced system has been aimed at carrying out several (up to N) tasks simultaneously. For this purpose it was required to apply groups of N (~ 10) channels able to complete up to K (~ 100) measurements during the given time interval of period T. Some operations of the channels are assumed to be fulfilled by common nodes of the system. Then the system engineering of data acquisition with the synchronized data interchange on the base of the system node allows one to find more economic structural solutions. However, characteristics of operations of both the channels and the node should be coordinated and high enough to provide the minimum waiting time of service taking into account the period of time and rate of the data flow. Further analysis of the procedure of operations generates the main requirements and approaches to develop the system engineering.

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THE PROCEDURE OF HOST-BASED DATA ACQUISITION

The host-based solutions of the type A, B and C for comparison are shown in Fig. 1.

The main operations of the channels include groups of synchronized measuring and quantization of the process variables. Synchronized data acquisition and exchange of links (communication channels) for data processing provide the feedback control. Levels of the main operations are applicable for the solutions based on the host with the link exchange of the system node. In the developed circuit (at first, type A, then B and C as the next step) the operations of the channels are fulfilled simultaneously in the assemblies connected via the timed link exchange for the host-based control. The conditions of parallel operations lead to more sophisticated modes of the system timing. Problems of the traffic of the data from all channels to control the pulsed facility require coordination of the amount of the data readouts and of the data flow for the link exchange of the system node. Estimations of the data readout rate and amount of data from the channels have been considered, first of all, under conditions of levels of A and advanced type B. The procedures at the node levels cause timing problems to be solved and also put the main requirements to the system node. Development of the system to increase the amount of the data and of the flow rate has led to higher requirements of the performance, especially when it is required to have the data convenient for the feedback control.

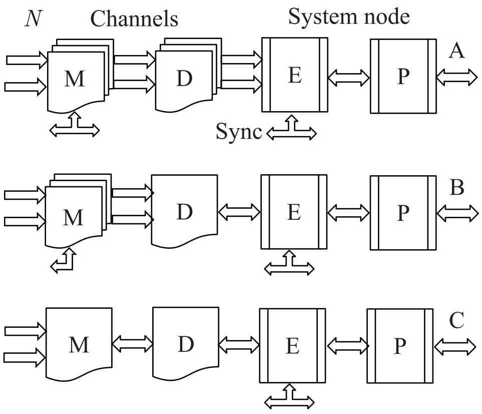

Fig. 1. Procedure flowcharts of A, B and C type. The operations M, D, E and P represent measuring, data acquisition, link exchange and process control

PERFORMANCES OF THE SYSTEM

Characteristics of the timed system define a possible rate of the data flow (the data readout) as well as the amount of the data of one channel, and also the number of serviced channels taking into account the choice of the timing mode.

Timed Readout of Group of the Data from One Channel. The required rate of the data flow for the system channel is sufficient if the time of data readout does not exceed the specified part of the period of time of measuring and data acquisition. For the cyclic run with a period of time T when service time $t < T$ and its factor is $m = t/T$, the lower limited rate of readout K data is calculated as $n_1 \geqslant K/mT$. At the given values of period T and the number K, the service factor of $m = 0.1$ is reached if the rate of the data flow exceeds 10^5 s^{-1}. The attempts to reduce this factor can increase the idle time of the output equipment for which the idle time factor is estimated as $(1 - m)$. Then the equipment will be used inefficiently.

Simultaneous Data Readout of the Group of Channels. The data transmission rate in comparison with the above-specified speed should be increased according to the following expression: $n_2 \geqslant n_1 N/A$. Coefficient $A < 1$ denotes a part of the operating time (within the interval between two runs) which depends on the time of the link exchange and preparation for data reading. If the readout time is $t = mT$, the rate is determined from the expression:

$$n_2 \geqslant KN/mTA. \tag{1}$$

At the given number of channels N and coefficient $A = 0.5$, the required minimum rate n_2 is more than $\sim 10^6\ \mathrm{s}^{-1}$. From this one can see what kinds of requirements are necessary for the given number of channels.

The coefficient of the idle time of the channel (the ratio of waiting time to T) is defined as

$$P_1 \leqslant (N-1)m/N. \tag{2}$$

The idle-time coefficient of the node (the ratio of the idle time to period) remains significant:

$$P_2 = 1 - mA. \tag{3}$$

Thus the equipment is used with modest efficiency.

Successive Data Readout of the Channels. Service of each subsequent channel having the order number of M will start with a delay $t(M-1)$, where t is the service period of time for the channel. The number of the channels working simultaneously with a node of service can be estimated from the following expression:

$$N \leqslant \frac{(T - t_1)}{(t_2 + t_3)}. \tag{4}$$

Time t_1 and time t_3 are introduced to take into account the preparatory operations during period T and also before each data readout. The time t_2 is the readout time of the data of the channel at the estimated rate of reading. Taking the conditions $(t_2 + t_3) = mT$ and $t_1 \ll T$, we have rate $n_2 = 10^5\ \mathrm{s}^{-1}$ at the required number N. As can be seen, using the latter technique many channels can work with one node even at the modest rate. For the channel expecting service the coefficient of idle time P_1 (defined by the ratio of time t_3 to the period T) is a small value at $t_3 \ll Nt_2$. For the system node the coefficient of the idle time is

$$P_2 = \frac{t_1 + Nt_3}{T}. \tag{5}$$

Taking into account requirements $t_3 \ll t_2$ and $t_2 = mT$, we gain the coefficient $P_2 = 1 - Nm$. That is much less than in the previous mode. In particular, it shows the significance of time t_3 reducing. This mode in comparison with the previous one is more efficient.

A Possible Queue of Requests of Servicing. It is of interest to consider the case when the request of service of the channel can arrive while the node is busy with service of another channel. The requests form a queue if their number at the same time exceeds the number of common nodes of the system. Such situations are characteristic for the system in the same "queuing" mode. Efficiency of the system when requests can occur at arbitrary time is illustrated further by the obtained characteristics of the idle time of the system (for a limited flow of requests, by queue definition [3]). The diagrams (Fig. 2) represent the dependence of the idle time of the channel P_1 and the node of the system P_2 on the number N of channels.

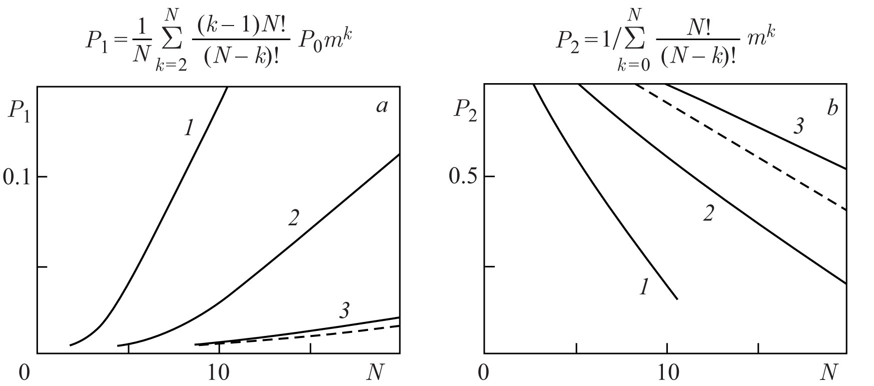

Fig. 2. Coefficients of the idle time P_1 (*a*) and P_2 (*b*) at the number N of channels. Graphs *1*, *2* and *3* are shown at the values of the factor m equal to 0.1, 0.05 and 0.025, respectively

The parameter m is equal to the ratio of the average time of service to the average time between the requests of the channels. P_0 is a probability that the common node is not engaged, and k is the number of the requests that appeared. When m is reduced the waiting time is shorter and does not exceed the servicing time if N is up to 8, 13 and 21, respectively. The above estimates allow one to select the requirements to the performance of the common node regarding the efficient load and a permissible delay.

Quantity of the Nodes. The consideration assumes the utmost permissible operation mode of the node during the runtime cycle of the order of ten tasks. To increase both the system productivity (or to reduce the waiting time) and the functional reliability, it is possible to use reserve nodes for parallel operations. In case of the doubled nodes (at $m = 0.1$) the idle time characteristics are close to the values for the node at $m = 0.05$ (graph *2*); however, the waiting time does not exceed the servicing time for a greater value of N. Efficiency of using three nodes (for the purpose of group service) is represented with dashed curves. A possibility of servicing the channels with rated productivity in case of a failure in separate nodes is considered while determining their number and the system structure.

Operations of the System Node. Basic features of the node are matched to service a group of the channels working concurrently. The data interchange is synchronized to the time controller of the system and to the synchronizer of pulsed facilities. High-speed performance and reliability of the node are related with efficiency of the chosen host-based solutions. Thus, its performance should be justified enough. From the above it is possible to see the utmost importance of the rate of the data exchange as well as of the time of preparation of connective operations. The transferable data are accompanied by the control signs to identify and accelerate the arranged processing. The function of identification of the channels reduces time t_3 for the data readout preparation. Such functions reduce "dead times" of the cycle which can be critical under conditions of the feedback control. The system node is used with a smaller P_2 at large numbers of K of parameters of processes and N of the operated tasks.

ADVANCED DATA ACQUISITION SYSTEM

The circuit of data acquisition (Fig. 3) includes measuring channels to monitor the groups of parameters to control pulsed facilities. The embedded channels for a consecutive sample of pulse parameters of the cycle, and the channels for combined check of parameter deviation and direct protection of the duty cycle extend the opportunities of the system.

Timed Data Acquisition to Control Pulsed Facilities. The timing controller TC and the multiplex logger ML are started at each running of the duty cycle. The converters of pulse amplitude AC and delay time DC start value sampling (with nanosecond timing), conversion and storage of parameters. Noise-resistant conditioners VC normalize the values of low-level signals. The measured parameters are saved on the data logging time.

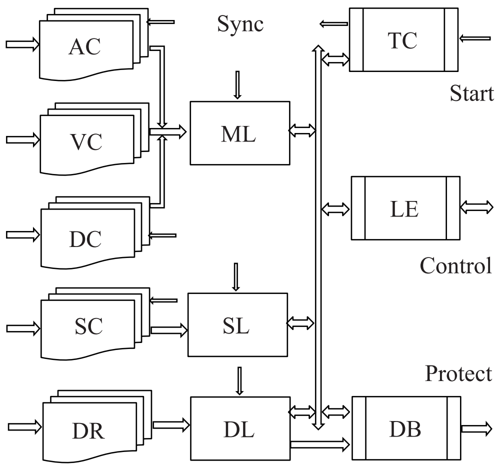

Fig. 3. The data acquisition system to control and protect the pulsed facilities

The logger provides data recording during the selected time part of the cycle (during a millisecond). The remaining time of the cycle is reserved for running data exchange to obtain a decision concerning further control of the working cycles. The timing controller and the link exchange unit LE of the node (with the interface of data processing) integrate the system (of type B) to back control.

Sequential Sampling of Parameters of Duty Cycle Pulses. The sequential pulse converters SC and logger SL are started at the duty cycle running. Then the combined sample and record of parameters of the trailing pulse or the pulse train are fulfilled repeatedly. The sequence of the K values of amplitude and nanosecond clock periods is registered for fast diagnostics of the parameters of the pulse (for example, its shape) or of the pulse train of working cycle.

Tracking of Parameter Deviations to Protect the Operation Modes. The identifying registers of parameter deviation DR (on the base of the comparators) and the logger of the detected deviations DL can directly control the protection logics DB. The state transition will be registered when the alarm levels of tens of parameters are defined. The protection logic allows one to lock execution of the working cycle immediately and then other operation modes of the facilities will be changed under emergency conditions. Besides, the data recorded in the logger will be transferred via the link exchange interface into the process controller of the system for the subsequent diagnostic and feedback control.

CONCLUSIONS

The technique developed for the host-based data acquisition system allows one to coordinate the procedures of synchronous measuring and data acquisition to control pulsed facilities of the linear accelerator. Efficiency of the data acquisition system has been gained at various modes of timing of the channels and the link exchange of the system node. The basic performances of the advanced system for feedback control match the available conditions of the running cycle of the linac section. The considered amount of the system channels and examined parameters take into account the possible doubling of accelerating sections. The presented system solutions and operating characteristics are developed taking into account further reduction of the time period of repetition and duration of the beam pulse, but it assumes the increase of the energy of electrons and the beam current of the linac.

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