HOST-BASED SYSTEM TO CONTROL THE ACCELERATOR

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Abstract

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

STATEMENTS OF A PROBLEM

Considered technique of synchronized data acquisition has been developed to control the linear accelerator of electrons LUE-200 of the neutron source IREN [1].

A multiplex system of timed data acquisition for monitoring parameters of the working cycle (at time period T, from one pulse of the electron beam up to another one, and cycle repetition rate $-1 / T \le 150$ per second) has been offered and tested while the linac LIU-30 and full-scale test facility IREN were equipped with instruments [2].

Timed procedures of data acquisition are applied in the host-based solutions for a group of tasks to supervise process variables and control pulsed facilities [3].

The advanced system is aimed at carrying out several (up to N) tasks simultaneously. For this purpose it require to apply groups of N (an order 10) channels, one able to complete up to K (\sim 100) measurements during the given time interval of the period T.

Some timed operations of the channels are assumed to be fulfilled by means of common nodes (with the timing controller) of the system. A link exchange of a node supports reading the data (at rate n) to feedback control.

Then procedure flowcharts of the engineering with the timed data interchange on the base of the system node allows one finding more efficient structural solutions.

Characteristics of operations of the channels and node should be coordinated and high enough to provide the minimum waiting time of service, taking into account the time period and rate of the data flow.

Key characteristics of channels and system node are coordinated to minimize a service time. Their idle time factors (P_1 and P_2) are examined, and also at possible queue of service requests.

The timing controller and link exchange of the node integrate the HB system, started at a working cycle. Diagnostics of process variables is complete for the cycle to feedback control.

Performance and number of serviced channels at chosen sync modes for such system are examined further.

The further analysis of operations forms requirements and approaches to develop system engineering.

THE PROCEDURE OF HOST-BASED DATA ACQUISITION

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

The operations of the channels include groups of synchronized measuring and quantization of the process variables. Timed 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. In the developed circuit (at first, type A, then B and C as the next step) the main operations of the channels are fulfilled simultaneously in the assemblies connected via the link exchange of the node.



Figure 1: Procedure flowcharts of A, B and C type.

The operations M, D, E and P represent timed measuring of process variables, data acquisition and link exchange with interface to control.

The conditions of parallel operations lead to more sophisticated modes of the timing. Problems of the traffic of the data from all channels require coordination of the data readouts and of the data flow for the link exchange.

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 requirements to the node. Development of the system on purpose to increase a data flow has led to higher requirements, especially when the data convenient for feedback control, are necessary.

Performance of operations at various timing modes of system is examined at complex requirements to pulsed facilities of the linac.

The amount and rate of the data gained during the accelerating cycle, attained number of channels which should be serviced, and also possible waiting time of operations, both for channels and node, will be considered

PERFORMANCES OF THE HB SYSTEM

For the cyclic run of measuring and data acquisition the lower limited rate of the data flow for the system is sufficient if the time of data readout does not exceed the specified part of the period of time T.

System characteristics define possible rate n of data readout just as amount K of the data of one channel and also the number N of serviced channels.

Performance of the system and the number of its channels are considered further for the selected timing modes, taking into account the specified key characteristics and estimated factors of an idle time for the channel and a node ($(P_1 \text{ and } P_2)$).

Timed Readout of Group of the Data of Channel

Plain read-out of K data from one channel is fulfilled during period T, when service time t < T and its factor m = t / T.

At the given values of T and K and service factor m = 0.1, the lower limited rate of data readout is calculated as $n_1 \ge K / mT$. Idle time factors $P_1 = m$, but P_2 are estimated as (1 - m).

Then the equipment is used inefficiently.

Simultaneous Data Readout of the Channels

The data transmission rate in comparison with the above-specified speed should be increased according to the following expression: $n \ge n_1 N / A$.

Coefficient A < 1 denotes a part of the operating time T (within the interval between two runs) which depends on the time of the link exchange and preparation for data reading. If the read-out time is t = m T, the rate is determined as $n \ge K N / m$ T A. From this one can see what requirements are necessary at given key parameters.

The coefficient of the idle time (the ratio of waiting time to period T) of the channel is defined as $P_1 \le (N-1) \text{ m / } N$. The idle time coefficient for the node: $P_2 = 1 - \text{m A}$, remains significant.

Thus the equipment is used further with modest efficiency.

Successive Data Readout of the Channels

Service of each subsequent channel having the order number of $M \le N$ will start with a delay (M - 1) t, where t is the service time for the channel. The number of the channels working simultaneously with a node service can be estimated as $N \le (T - t_1) / (t_2 + t_3)$.

In this case the times t_1 and t_3 are introduced to take into account a time of preparation of data readout for all channels and each channel. The time t_2 is readout time of the data of the channel at the estimated rate of reading.

Taking into account the conditions $(t_2 + t_3) = m T$ and $t_1 \ll T$, we have the modest rate $n = \sim n_1$ at the number N (<18). Then the channels can work with one node even at the modest rate.

For the channel expecting service the coefficient P_1 defined by the ratio of time t_3 to period T, at $t_3 < N t_2$, is small. For the node the coefficient of the idle time is $P_2 = (t_1 + N t_3) / T$.

Taking into account requirements $t_3 \ll t_2$ and $t_2 = m T$ we gain the coefficient $P_2 = 1 - N m$. 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. Such situation when requests can occur at arbitrary time is characteristic for the system in the same "queuing" mode.

The system efficiency is considered for a limited flow of requests [4].

The parameter m is equal to the ratio of an average time of service to the average time between the requests of the channels. And also P_0 is meaning a probability that the node is not engaged in servicing, and k is the number of the appeared requests.

Figure 2 shows the dependence of the idle time factors on the number of the channels.





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When the factor m is reduced, the waiting time is shorten and thus does not exceed service time for bigger number of the channels (to 8, 13 and 21, accordingly). The estimates help one to select the key parameters.

Performance and Quantity of the System Nodes

Requests of service form queue if their number at the same time exceeds number of nodes. The nodes should be reserved for parallel operations to increase performance just as reliability of system. Possibilities of service in case of a node failure also are in view.

At using the doubled nodes the general characteristics accordingly change (the graph 1, in a Fig. 2, comes nearer to the graph 2); however, waiting time does not exceed servicing time for a greater number N (to 20). The dashed curves show efficiency of usage of three nodes. Efficiency of use (it concerns idle time at the chosen timing for the solution) grows under the given conditions.

The sent data is accompanied by signs to identify process variables and thus to reduce time of data exchange and preliminary operations (t_3 etc.). It allows reduce "dead times" of each cycle which are a key problem for timing under conditions of feedback control.

ADVANCED HB SYSTEM

The HB system includes the N channels and a node (as shown in Fig. 3) to monitor the process variables and control pulsed facilities. Embedded channels for a consecutive sample of pulse parameters and for check of parameter deviations extend the system opportunities.



Figure 3: The system to control and protect the linac.

The system includes the next units:

TC, LE - timing controller and link exchange of a node; ML - timed multiplex logger (one unit for 32 tasks); AC, DC, VC - converters of amplitude, a delay and value; SC, SL - sample-hold converters and serial logger; DR, DL - a register of identification and deviation logger; DB - logics of protection and lock a working cycle, etc.

Timed Data Acquisition to Feedback Control

The units of the node (with the data processing interface) are started at running of a cycle. They integrate the HB system (of type B). The data interchange has sync with timing controller of the system and pulsed facilities. The converters start sample (with a nanosecond timing), then transform and keep pulse parameters for the period of logging. Also the conditioners of value normalize the low-level signals.

The multiplex logger records group of the data in a given time (to a millisecond). Remaining time of a cycle is reserved for data exchange and diagnostics to obtain a decision and control the cycles.

Consecutive Sample of Pulse Parameters

After the beginning of the working cycle, the strobes of sample-hold converters are started and repeatedly follow. The sequence of K values of amplitude with nanosecond discrete timing is registered.

Record of series of parameters of trailing pulse (its shape etc.) or pulse sequences is fulfilled for fast diagnostics of a series of pulse parameters, to control the mode of pulsed facilities.

Tracking of Deviation to Protect Cycle Mode

The identifying registers and the logger of the channels for monitoring the parameter deviations can directly control the protection logics. The state transition is registered when the alarm levels are defined.

The protection logic allows to lock of a working cycle immediately and then to change operating conditions under emergency.

Besides, the data recorded in the logger will be transferred via the link exchange interface into the process controller for subsequent diagnostic and control.

CONCLUSION

The developed HB technique allows one to coordinate the timed procedures of measuring and data acquisition, to control the linac. Efficiency of the HB system has been gained at selected modes of timing of the channels and link exchange of the node. The performances of the advanced system match the available conditions of the running cycle of the linac. The examined system parameters take into account doubling of accelerating sections. The presented solutions and characteristics are developed taking into account further reduction of the time period of repetition and duration of the beam pulse.

REFERENCES

- [1] Ju. Becher *at al.*, "The LUE-200 accelerator at the IREN facility: current status and development", *Physics of Particle and Nuclei Letters*, vol. 11, no. 5, pp.1029-1039, 2014.
- [2] V.N. Zamriy, "Study of automation sources of data acquisition", *Nuclear Electronics and Computing*, Proc. of the XXI International Symposium, Varna, Bulgaria, 2007. JINR, E10,11-2008-37. Dubna, 2008, pp. 455-460.
- [3] V.N. Zamriy, "Host-based data acquisition system to control pulsed facilities of the accelerator", *Physics of Particles and Nuclei Letters*, vol. 13, no. 5, pp. 601-604, 2016.
- [4] V. Ja. Rosenberg and A.I. Prokhorov, *The Theory of Mass Servicing*, Moscow, Soviet Radio, 1962, 254 p.