DIAGNOSTIC FRONT-END ASSEMBLIES FOR IREN FACILITY LINAC CONTROL

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Abstract

The approaches to modular instrumentation systems under discussion, provide various allocation levels of signal processing, as well as the supervisory levels included into the control structure for the designed facility. The system nodes, which provide handling of signal groups, as well as desirable on-line data processing, have been offered to equip the pulsed facility. This work considers some features of the distributed assemblies intended for the timed data taking and control of the electron linear accelerator. The front-end assemblies for diagnostics of duty cycles and state transitions for protection control of IREN facility linac, are developed. Besides, the realized front-end signal-processing units are presented.

INTRODUCTION

The considered instrumentation of the pulsed facility has been developed according to the project for the source of intense resonance neutrons (IREN). The designed facility includes a neutron target and linear accelerator of electrons (linac LUE-200) [1]. The linac equipment includes powerful klystron SLAC5045 and RF (2856 MHz) power multiplier, a pulse modulator and a power supply, a synchronizer and an electron gun driver, as well as a cooling thermostat, the vacuum and other environmental subsystems. The expected repetition rate of beam pulses is ~0-150 sec^{-1}.

The instrumentation should include the timed data-taking system [2] to diagnose and control each linac cycle. Some of these problems of diagnostics and control for the pulsed facility are considered in the reports [3, 4]. The diagnostics schemes of the both – cycle parameters and state transitions, have been developed for fast control and functional-mode protection with a possible fast locking of the cycle (during microseconds). Front-end assemblies for processing of various signals have been developed, too. Some features of the assemblies are considered below.

CONDITIONS FOR INSTRUMENTATION

There are signal groups from detectors and the transducers allocated throughout the facility whose parameters are useful to find troubleshooting and identify instability. The front-end instruments inspect signals, as well as parameters of the accelerator process while the output drivers control the environment subsystems and, finally, – the incident wave of the klystron, and cavity resonance frequencies. Some parameters are available only locally or monitored by slow instruments that cannot recognize fast transition processes. New distributed front-end assemblies for the timed diagnostics and duty protection control, should fulfil sampling and recording of the signal parameters practically simultaneously. Then it will be possible to collect the parameters at the given intervals or at a fast state change and the facility shutdown. Thus, the signals will be processed to identify quickly beam issues, reducing the facility downtime.

A set of signal-processing assemblies and core processors interacting in the distributed modular system should be one of the instrumentation platforms for fast data-acquisition and control. The assembly can contain the linked control means and data-acquisition modules with the analog and digital signal-processing units (DSP-based units). The distributed assemblies may interact with the computer-based processors via the network using control messages and required fast links for data taking on-line.

The scheme of the distributed signal processing is justified by known conditions on nuclear-physical facility. The peculiarities of the assembly components are determined by their application in the areas having the limited access (while radiation) and service period restrictions. The requirements to the facility efficiency determine the solutions reducing equipment downtime and a repair-time of the components.

Thus, not only steering algorithms determine quality of the system, but also operability and serviceability of its blocks and links. The operability and maintainability of the pulsed radiofrequency facilities demand on-line diagnostics to minimize the downtime, while the availability requires application of reliable hardware components, redundancy, and robust algorithms. Thus, the tasks of timed data taking and fast protection at a remote control determine the distributed signal-processing frame, especially at pulsed, radiofrequent and industrial interferences. For the components located on electrical potential of the facility and on the ground potential, it is required to accomplish the isolated connection, and also to the host. These conditions have resulted in designing the robust controller logics for assemblies with protective interlocking.

LEVELS OF THE SIGNAL PROCESSING

Requirements of reliable “turnkey” operations and sophisticated diagnostics have specified the hardware control of a low level, and the high-level control means. The approaches to modular instrumentation foresee various distribution levels of front-end conversions and signal-processing sites. The levels of signal processing just as the supervisory levels can be also included into the control frame for the designed facility.

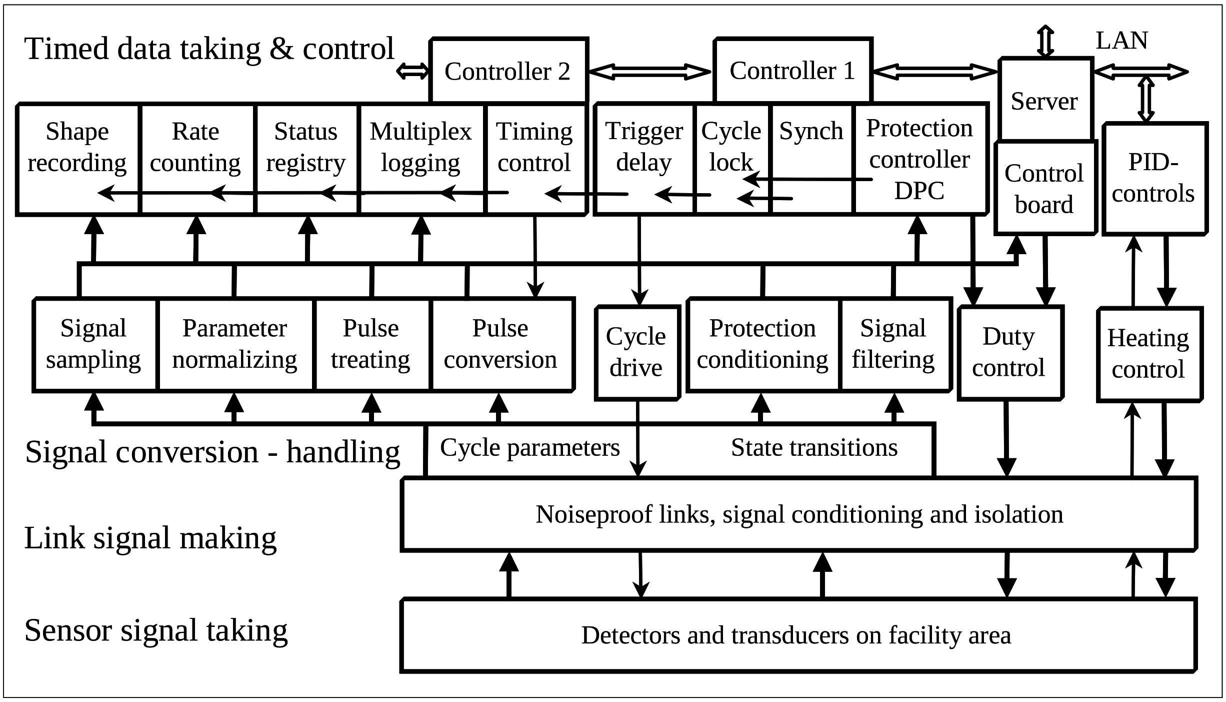

Figure 1: The levels of signal processing for timed diagnostics and protection control.

The multilevel architecture of the distributed signal processing is shown with the example of the implemented parts of the assemblies for the timed diagnostics of cycle parameters and state transitions to control the duty cycle protection (Figure 1). The levels of distributed processing are shown taking into account the conditions with the access limitation on the facility. They include the first level of signal detectors and transducers allocated on the facility area (Sensor signal taking). The next level is intended for signal conditioning and devices isolating for noiseproof links (Link signal making). Further remote levels (Signal conversion – handling; Timed data taking and control) include various units for sampling, conversion and signal-group processing, and then the modules for data acquisition (as DSP) and duty-protection control (on the base of the DPC controller).

The task of synchronous sampling and processing of various signals is parallelized in branches, which fulfil individual operating sequence. Here the pickup signal reading and the noise-resistant transmission are fulfilled as well as the timed signal sample and conversion, and a fast treating. This includes necessary filtering and rejection of various interferences, and range normalization of examined parameters before diagnostic computing. The programmable modules can include DSP-based components and the link interface for the local area network server. The distributed assemblies linked for synchronous monitoring and control, should interact while transmitting results of fast signal processing and obtaining the control data.

FRONT-END ASSEMBLIES

The signal converters allocated on the facility, as well as the front-end assembly for the low level control, should have a frame, whenever it is possible, simplest and robust one. Besides, it is desirable to use interchangeable components of the own system to make it easier for the development and maintenance. Off-the-shelf signal-processing instruments (based on DSP and programmed logic controller) and standard PC-based components used for in-house system development, correspond to this idea. The known solutions on the industrial modules and controllers are used predominantly for status data taking and slow control of the magnets, vacuum, temperature, etc. Here the local network is used for communications to the low-level control devices, as well to a PID-controller of the implemented steering system of the thermostat for the linac.

To meet the requirements to the higher data throughput, the system assemblies will be based on a signal-processors set (as DSP-cards). Their digital parts, as well as devices based on PLC-controllers, can include firmwares for roughing-out during the order of microseconds. They can be implemented also in the units with the field programmable gate arrays. Then the slow algorithms (the order of milliseconds) for data traffic and so on, are executed at the level of the core processor only.

The same way, our homemade modular assemblies for fast taking the cycle parameters (at rates up to 10^5 sec^{-1}) are composed of front-end units for multiway signal processing (up to 8 analog input signals each). They are distributed on diagnostics assemblies and control, and interconnected to facilitate triggering of the duty cycles. The modules are timed by the linac start-up synchronizer. They can contact the server connected to the Ethernet as well as the slow-control subsystems. To develop further the fast control subsystems, possible solutions are based on application of the distributed front-end assemblies interacting with the network server. The various assembly units have been developed and tested for multiway signal processing, synchronous data taking and fast duty protection.

KITS OF THE FRONT-END UNITS

The presented kits of multiway units provide the distributed parallel processing of various groups of signals and desirable real-time handling of the parameters. The advanced units of the front-end subassembly for signals processing at remote data taking, are partially homemade. Some examples are shown in the units for various signals of a low level, and of low frequency, for parameters of a time and pulse amplitude, and treated narrow pulses. Main features of the kit of blocks are also surveyed, thus the attention is focused on the front-end characteristics.

The subassembly of normalizers of low-level signals includes the noise-resistant processing units for nonlinear transducers, as thermocouple TC or resistance temperature detector RTD, and for various linear sensors as well. The universal unit is built to normalize signals about millivolts with compensation of a TC cold-junction potential and initial voltage of the RTD or others sensors. The precise instrumentation circuit with microvolt resolution based on high-stable operational amplifiers, has lapses of less than 0.1% and drift ~0.1 μV/°C, a common-mode rejection – up to 120 dB and normal interferences – 40 dB at 50 Hz, and input impedances – 10^8 Ohm. It is possible to program the handling modes, to select subtracted voltage and its polarity by using the external compensating voltage or the built-in reference source having the stabilized and temperature sensitive outputs, and a pin-programmable range mode. Besides, it is possible to set a signal amplifying and its polarity, a stabilized current for the RTD platinum sensor, and to anchor the “isolated” input terminal to a common potential.

The unit of a pulse normalizer is intended to treat the millivolt-signals of very low frequency (of ~0-100 Hz). The front-end circuit includes a highly sensitive discriminator-booster and a threshold former based on the quality operating amplifier and the Schmitt trigger. The peaker output and the pulsed driver are used to transfer data to the remote preset-counter or the expenditure meter of cooling for the thermostat of the accelerating section. The given current of a reference source creates the auxiliary magnetic field modulated by a curl of the flow-rate detector.

The converter units of the duty pulse parameters fulfil fast sampling and a long-term storage of the amplitude values and delay time interval, converted to the voltage signals. Here nanosecond circuits of timing of the converted interval to a pulse form, are applied. There is a possibility to use gated pulse selections and the strobed sampling (200 nsec) with its lock during the storage period (1-10 msec) before the hold reset. This, as well as the isolated front-end circuits with a small transfer capacitance, can appreciably improve the noise cutting-off (more than 60 dB). Both converters based on a custom-made microassembly of the pulse stretcher with a high-linear charge of a storage capacitor, have the lapses less than 0.1%, at slew rate 50 mV/nsec.

The fast processing blocks are intended for taking the amplitude parameters from the detectors of narrow pulses (about 100 nsec). One of the units is intended to define the complete amplitudes and to compute some functions, for example, for the total current I and beam positions. The sensors (such as Rogovsky belt) can have two pair of outputs, respectively, for coordinates X and Y. Thus, it is necessary to fulfil the algorithm calculation for the full sum of the amplitudes (I=X1+X2+Y1+Y2), and the difference for each pair (X2-X1 and Y2-Y1) with the subsequent normalization to the sum value, taking into account possible fluctuations of the beam current. The last scheme is based on fast operational amplifiers to perform the amplitude computations with the minimized delays (less than 10 nsec, at possible duration of fronts for the front-end and output pulses – 10 and 20 nsec, respectively). The results of pulse treating can be recorded at once and distributed in modules (as DSP and DPC) of the assemblies composed for the timed data acquisition and control of the duty protection for the developed facility.

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