THE USAGE OF TRANSIENT RECORDERS IN THE DAILY HERA MACHINE OPERATION

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Abstract

Many parameters of HERA machine components such as RF systems or quench protection as well as important beam parameters are continuously measured using transient recorders. In general, these recorders are not synchronized among one another and sample the data with very different rates ranging from 200 Hz to 50 MHz. At present, work is going on to integrate the different existing transient recorders into a global system. The article reviews the transient recorder hardware in operation at HERA. In addition, the proposed trigger distribution based on the HERA Integrated Timing system as well as the software concept to archive, retrieve and display the data will be described.

1 INTRODUCTION

The HERA accelerator complex is a proton-electron collider. A proton beam of more than 70 mA is injected at an energy of 40 GeV into a ring of superconducting magnets and accelerated to 820 GeV. Electrons are transferred to HERA at 12 GeV and ramped to 27 GeV using conventional magnets. Typical electron currents are about 40 mA. A successful fill remains stored in HERA about half a day. Less than 50 % of the time scheduled for physics experiments can be used for data taking. The remaining fraction is mainly dominated by the filling, ramping and tuning processes. In particular, the filling of protons takes a long time. Therefore, the most unfavourable situation in the daily operation of HERA is the loss of one or even both circulating beams. If the origin of the beam loss can be uniquely identified, improvements of the machine operation or the technical components can be performed. However, a loss not understood contains the risk of a new loss during the following run. Besides a reduction of the running efficiency, losses can generate dangerous situations for the superconducting magnets and radiation-sensitive components close to the beam pipe of the physics detectors.

To identify the reasons for beam losses, many parameters of HERA machine components like RF systems or quench protection as well as important beam parameters are continuously measured using transient recorders. In general, these recorders are not synchronized among one another and sample the data with very different rates ranging from 200 Hz to 50 MHz. This lack of synchronization often does not allow us to disentangle the temporal or causal development of a beam loss. At present, work is going on to integrate the different existing transient recorders into a global system. In addition, a new universally usable recorder is currently being developed. This article reviews the transient recorder hardware in operation at HERA. The proposed trigger distribution based on the HERA Integrated Timing system as well as the software concept to archive, retrieve and display the data will be described.

2 EXISTING TRANSIENT RECORDER SYSTEMS

At present, more than 100 parameters such as phase and amplitude of the different electron RF transmitters as well as of the feeding HV power supplies are recorded at different locations along with the electron current. Commercially available PC boards (Bakker BE 490) with 8 inputs each are used. The sampling rate and the storage capacity per channel are 100 kHz and 20k byte, respectively. The analog signals are converted by a 12-bit ADC. The data recording can be stopped by an external or an internal trigger. The software runs on top of Windows 3.1 and has no networking functionality. The different PC's can be remotely controlled via PCAnyWhere. Only a couple of parameters of the proton RF system are continuously measured. The system is controlled and operated by a front-end DOS-PC sampling the data every some milliseconds. An external trigger is not implemented.

The HERA quench protection system for the superconducting magnets is the most prominent user of transient recorders. For diagnostic purposes more than 1400 voltages measured across the magnets and with respect to ground are stored in case of a quench. The transient recorder boards used have been developed at DESY as dedicated measuring devices. The boards are distributed in the HERA tunnel along the magnets. The sampling rate and the number of data samples per channel are 250 Hz and 1k, respectively. A 12-bit ADC measures the voltages between +5 V and -200 V or +25 V and -1000 V. A cluster of about 20 boards is read out by a VME-CPU via a commercial field bus (CAN). The data taking is stopped one second after the corresponding CAN broadcast message. The control, archiving and display software has been written at DESY using C and Visual Basic.

The proton beam diagnostics makes extensive usage of dedicated post-mortem memories. The proton beam loss rates are measured at about 250 locations every 5 ms. A history of 128 data samples is stored as well as 128 average loss rates integrating over 128 measurements. At almost the same locations, the proton beam orbit is recorded. Horizontally and vertically, the last 1024 turns are stored as well 256 closed orbit data samples gained by averageing over 128 turns. In each case, data taking is stopped by a common hardware trigger released from the beam loss detection or the quench protection system. The data are read out via DESY standard field bus lines (SEDAC) by a DOS-PC belonging to the HERA control network. Front-end control and display application software are written in C and VisualBasic, respectively.

The current pulses of the 12 kickers and septum magnets necessary to eject the beams from the booster accelerator PETRA and to inject the beams into HERA are recorded at every transfer process. Standard HP digital scopes and PC ADC boards from National Instruments are used. The sampling rates differ from 250 kHz for septum pulses to 5 MHz and 50 MHz for kicker pulses. Per pulse 512 data samples are taken. The Scopes are controlled by PC's via GPIB. A LabView application displays the traces.

3 DEVELOPMENTS FOR FUTURE USAGE OF TRANSIENT RECORDER SYSTEMS

At present, work is going on in order to enhance the profit which can be gained from the usage of transient recorder systems.

- Improved functionality of the power supply controllers to store permanently with 12-bit resolution the set value of the current as well as the actual values of current and voltage. The sampling rate will be less than 1kHz. More than 1000 data samples per channel can be stored. The data stored in about 680 controllers will be read out via SEDAC lines by a server responsible for all magnets and currently under development.
- Enlarging the number of measured parameters. A couple of signals from the electron and proton multi-bunch feedback and the electron tune controller will be recorded in the future. In addition, the currents of the electron and proton reference bunches as well as more parameters of the HV power supplies for the electron RF transmitters will measured continuously.
- Implementation of networking capability into the software of the Bakker BE 490 boards. The software has been completely re-written at DESY to support the VxWorks operating system on PC hardware. This allows us to integrate the boards into the HERA control system keeping the same flexibility as in the original Windows 3.1 environment
- Development of a low-cost multi-purpose transient recorder at DESY with moderate sampling rate. A cluster of 8 or 16 channels will share the same clock and memory. The probes with the ADC's can be configured according to the dedicated measuring requirements (isolation to ground, amplitude and band width of input signals). Analog and digital electronics can be separated by about 20 m. In addition, 12 digital input ports are offered per cluster, which can be logically combined to generate stop trigger conditions. Also a simple threshold as well as a software trigger functionality will be foreseen. The sampling rate will be about 100 kHz which is twice the revolution frequency of HERA. The sampling process can be synchrozid to the HERA clock system if requested. It is proposed to connect the clusters to a field bus e.g. CAN or to an Ethernet line.
- HERA-wide trigger distribution for a simultaneous stopping of data tating of all or a subset of all transient recorder systems. The HERA Integrated Timing (HIT) system offers the possibility of distributing events along HERA. Independent of location at HERA, the HIT system guarantees the synchronization of the events. Two trigger conditions are foreseen: (1) proton beam loss and (2) electron beam loss. The generation of triggers can be inhibited by additional conditions like beam energy or beam current thresholds as well as by a operator or control system request. In addition, triggers can be released by software events.
- Integration of all different transient recorder and post-mortem systems into the HERA control system which will be described in the following section.

4 SOFTWARE ARCHITECTURE FOR AN INTEGRATED ARCHIVE SYSTEM

A common application to remotely operate the various transient recorders and post-mortem systems e.g. to set a trigger threshold is not practicable. The systems are mostly part of complex technical systems and will be operated by dedicated applications.
However, starting the archiving of the data after a freeze trigger and the retrieving of the data for display and analysis puposes must be handled in a common way. Due to the very different hardware and software concepts a heterogeneous software architecture as shown in Fig. 1 with the following specifications has been chosen:

- client-server prinicple,
- modularity, distribution of functionality over 3 software layers (front-end, middle and application layer) reflecting the different needs of the different systems, easily adding of components in all layers,
- distributed archiving, shared usage of all archives, no standard data base format,
- standardized interface to the network using in-house Remote Procedure Calls (RPC) based on IP sockets,
- open for a wide range of platforms (UNIX-like systems, Windows NT),
- open to add commercial data bases such as Oracle or future software standards like JAVA applets.

Attached to each Archive Server is a set of Device Servers reflecting different transient recorders. If the data taking of any transient recorder channel (Device) is stopped by an external or internal trigger the corresponding Archive Server will ask an Event Server for a unique event number (Unix time stamp). All requests even from different Archive Servers within a short time interval are tagged by the same event number. The Archive Servers start their archive processes locally and store all data delivered from the Device Servers in a unique way. A standardized gobal data header is added to each archive and a local header is added to the data set of each device which has stopped sampling. The global header contains all information to characterize and select the archive event, e.g. the event number, the number of stored data sets or a comment. The local header consists of individual information such as sampling rate, number of data samples or number of pre-trigger values which are necessary to display the data. During the archiving the Archive Server does not accept any other event number. After the completion of an archiving process the corresponding Archive Server reports to the Event Server the names of the Device Servers which have delivered data for this particular event.

The Event Server stores a list of all event numbers and the additional information obtained from the various Archive Servers. It creates automatically an event code which contains encoded information to be used by filtering routines. A similar event code is generated at the Archive Server level.

All triggers distributed by the HIT system are marked with the current HIT time stamp (Trigger Server), i.e. the actual value of the revolution counter. This time information allow us to correlate data sets generated even by different trigger sources.

To display data by an application client, first a query is sent to the Event Server to obtain the event numbers and the contents of the archives stored within a certain time interval. In a second step the Archive Servers are asked to provide more specific informations about the data sets stored as available from the global and local data headers. Finally, the application requests the measured data to be displayed.

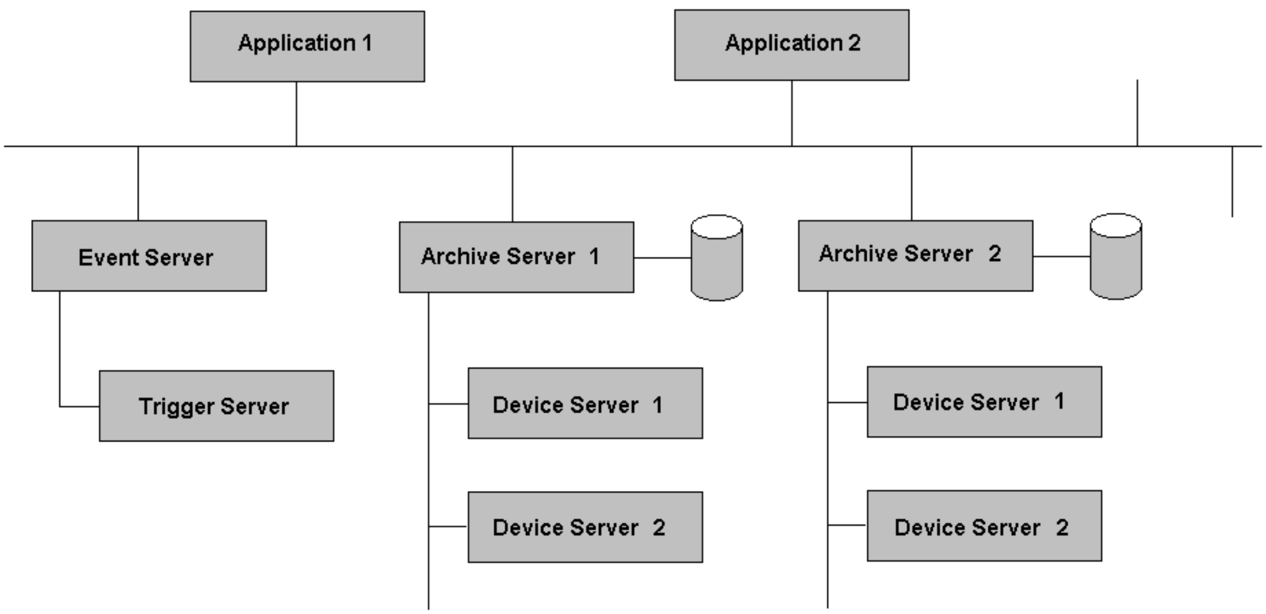

Figure 1: Software Architecture for an Integrated Transient Recorder Archive System

5 STATUS AND OUTLOOK

The software modules described in sections 3 and 4 are currently developed. The production of the hardware to distribute triggers via the HIT system is almost finished. The design work for the low-cost multi-purpose transient recorders has been started. It is expected that all transient recorder and post-mortem systems already existing will be integrated into a common system at the beginning of the 1998 running period of HERA. Additional systems will be added in the future according to the availability of the new hardware components.

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