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Design for Steady State Operation of LHD Diagnostics Control System

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Abstract

The LHD project is planning to have the long-pulse plasma experiments of about an hour in addition to the 10-second short-pulse experiments. These operations require the realtime control and monitor system along with the ordinary CAMAC system, and the distributed VME computers with their realtime operating system Tornado (VxWorks) will be individually applied for the LHD 20 or 30 kinds of diagnostics. The substantial limitation of the realtime systems that they are inevitably poor at fast data sampling requires the iterative CAMAC data acquisition for the precise sampling of physical analysis. These functional separation between the batch data acquisition by CAMACs and the realtime device management by VMEs is the essential idea of the long-pulse operation of the LHD data processing system..

Keywords

LHD, steady-state operation, long-pulse experiment, diagnostics control system, data acquisition, VME, CAMAC

1. Introduction

The LHD data processing system is expected to take 600 – 900 MB of diagnostic data totally in a 10-second short-pulse discharge experiment. These amount of data will be produced almost independently by the individual diagnostic devices whose variety goes up to 20 or 30 kinds in LHD, as shown in Fig. 1. As for the device control of these diagnostics, their operation channels become quite diversified and complicated because each diagnostics utilizes many kinds of hardwares, controllers and communication linkages which are much specialized for it.

These huge amount and diverse kinds of experimental data enforces us to adopt the fully distributed data processing and device management system, rather than the ordinary concentrated one which often uses a supercomputer called mainframe. Necessary conditions toward the LHD data processing system are to complete to acquire and process whole diagnostic data within 100 seconds after every discharge end. In order to satisfy them, the LHD data acquisition system was obliged to utilize the parallel tasking structure and reduce the data processing load of the individual element, such as data I/O ports or CPUs (central processing units). The principles for the new LHD data processing and device management system are as follows [1];

1. complete parallel distribution for each diagnostics device
2. functional separation using network client/server model
3. 100 Mbps FDDI-based fast switching network
4. object-oriented method as programming manner
5. commercial-based distributed database.

Modern technologies of high-performance personal computers (PC), whose capability become comparable

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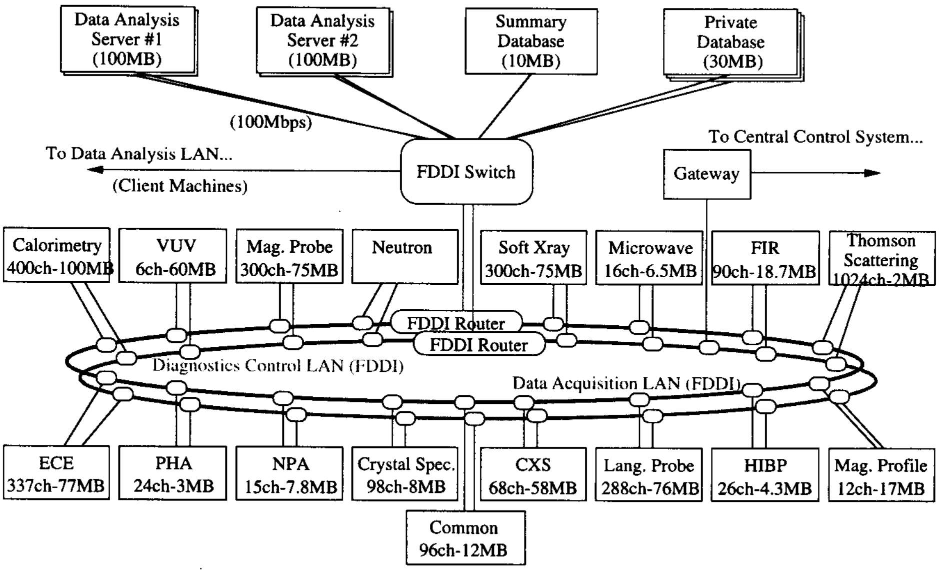

Fig. 1 Schematic view of the distributed diagnostics and the FDDI-based fast networks [1].

with engineering workstations (EWS), are also quite suitable for distributed and parallel data processing system because their cheaper cost enables to introduce more CPUs and machines.

The long-pulse discharge experiment of about 1-hour will be also planned in the following experimental periods. The total amount of acquired data will be certainly enlarged due to the longer duration. The most significant condition for the long-pulse experiment, however, is neither the total data amount nor the variety of control channels but that it requires the realtime data processing, transferring, and display within the discharge duration.

In the following sections we mention about the parallel distribution and functional separation at first, and how we organize the relationship among lots of computers according to the idea of the client/server model. Afterwards, the way of their realtime operations which deal with the quasi steady-state experiments will be described.

2. Structure of LHD Data Processing System

In order to apply the distributed structure into the LHD data processing system, the computers are divided into two categories of the data acquisition and the diagnostics control. The parallel distribution is also applied for individual diagnostics, and the two kinds of server computers are installed for each diagnostics as shown in Fig. 2: One kind is the data acquiring and storing computer which govern the CAMAC digitizers and databases, the other is the diagnostics controlling computer which interactively manage and continuously monitor the diagnostic devices in realtime. The former uses so-called AT-compatible PC and Windows NT OS, the

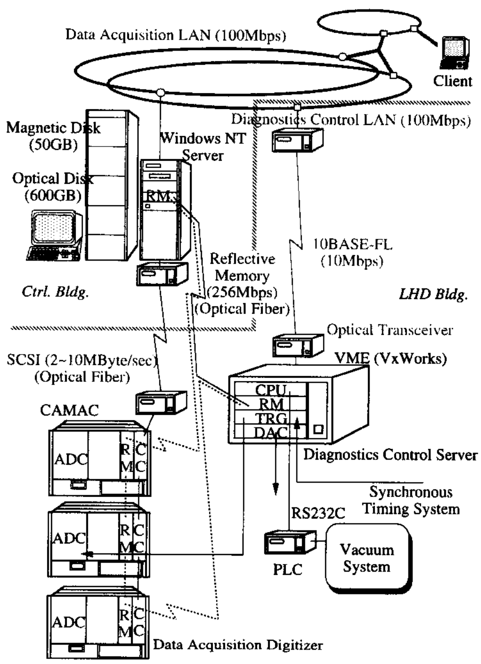

Fig. 2 A basic element of the CAMAC data acquisition and VME device control/monitor system: This set will be applied for each kind of the LHD diagnostics device. The dotted line means a future extension for the event-driven data acquisition.

latter does 68040-based VME and realtime OS Tornado, which is previously known as VxWorks. Both kinds of server computers will be independently stationed for every diagnostics of 20 or 30 kinds.

In addition to the parallel distribution of server computers of two categories, further functional separation between server and client computers will be also effective to provide the advanced graphical user interface (GUI). The computer loads of the data visualization and complicated analysis are often unrelated to the data processing sequence following after a discharge experiment. Popular 2-dimensional or 3-dimensional analysis and visualization make heavy CPU loads, and a private CPU for each user will become more desirable. As a good solution of this problem, the network client/server model can be preferably applied between data acquiring and storing servers and user-interfacing clients.

Fast network connections are indispensable for the mutual data transfer between those separately arranged computers. Especially among the data acquisition server computers, the fast mutual linkage and close concurrent cooperation could materialize a virtual macro-machine, which the client computers can send requests to and receive answers from. In other words, this virtual machine uses fast network links as its internal system bus. They exactly organize a massive parallel-tasking multi-processor system with loosely-tied communications [2].

3. Diagnostics Control and Realtime Monitoring

The LHD control system has four sub-clusters of (i) the experimental control, (ii) the torus control, (iii) the device control, and (iv) the diagnostics control. The first manages the central operation computer and the discharge sequence with the master timing system, the second behaves as the torus supervisory and controls the vacuum system, the magnetic field coils, and the cryogenic equipments. The third is for the plasma heating and its power supply system, and the last operates every diagnostics device.

As far as the diagnostics control system is concerned, the data amount of the device control or monitoring is not so large, and thus the parallel data paths are not necessarily indispensable for the wide transfer bandwidth. The large number of control or monitoring I/O channels, however, requires the distributed management computers. It is mainly because the device control and monitoring generally requires the realtime processing, however, the interrupts handling capability of most computer processors is generally less than about 1k interrupts per second regardless of its kind. As a result, we decided that diagnostics control computers should be installed for every diagnostic kind as the data acquisition computers.

For the diagnostics control, we adopted the VMEbus system with a typical module set of the Motorola 68040-based CPU module, A-D/D-A converters, digital I/O modules, communication ports of RS-232C and GP-IB, and others. Required conditions toward them are as follows;

1. realtime remote manipulation of active equipments
2. realtime status monitoring
3. timing trigger/clock system management
4. hardware interlocking surveillance.

The timing distribution system which is important both for the diagnostics control and the data acquisition digitizers is usually used as preprogrammed, however, it will require a realtime management when handling the realtime message distribution.

As for the network linkage of the VME computers, we have adopted the fiber-linked Ethernet (10BASE-FL) ports which also provide the electric insulation by means of optical fibers. They are connected to the switching hub which has 10BASE-FL ports and filters unnecessary packets for reducing the communication CPU load. For the interactive communications between the diagnostics control VME computers and their remote operation terminals, the remote procedure call (RPC) package of the ONC RPC 4.0 has been applied [3]. The RPC itself is classified into the upper protocol layer, namely, the presentation layer of the internet TCP or UDP transport layer, and it reduces the programmer's burden of directly managing the lower network layers by means of concealing them.

The protective data transfer from the VME computers to the storages are established through the reflective memory system which has been newly developed in order to reflect one's memory image onto the other's. Thus, the two different kinds of server computers of PC and VME are linked by the different bus-interfaced reflective memory boards of PCI-bus and VMEbus.

4. Extension for Steady-State Operation

As mentioned in the previous section, the LHD diagnostics control system based on the VMEbus has the capability to cope with the realtime device control and monitoring for 1-hour long-pulse plasma experiments. The typical sampling rate of the realtime data acquisition by the diagnostics control computer is about 10 Hz. By every 0.1 s sampling, the diagnostics computer can acquire, calculate, judge, transfer the datum which will be displayed to the observers in realtime. Especially for the feedback control of the diagnostics, the realtime processing is indispensable to continuously control the active equipments. Anyway, the diagnostics control computers can provide the 24-hour continuous data acquisition and the simultaneous time-evolution display if the sampling rate is rather coarser than 10 Hz.

Some operational modification, on the other hand, will be surely necessary for the CAMAC data acquisition system. The physics measurements usually require fine sampling rates, whereas the local memory capacity of the CAMAC module is much less than for 1-hour continuous sampling. Consequently, their iterative operation through AD-conversion, record, transfer, calculation, and store seems to be a good solution with the least modification under the condition of using their ordinary transient recorders. A typical sequence of the cyclic behavior of CAMAC systems compared to VMEs is shown in Fig. 3.

Naturally it is also possible to take a rather coarse sampling rate in CAMAC modules. In order to have a time-evolution display of the seamless data during 1-hour long pulse experiment, however, plural sets of their modules and transfer paths have to be installed in parallel and the cyclic operation between them will be required [4]. It is because the CAMAC property cannot provide the realtime data transfer simultaneously with the AD-conversion.

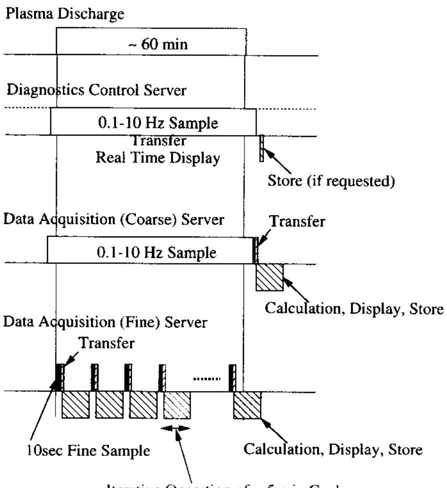

Fig. 3 Behavior of the LHD data acquisition system in long-pulse experiments: VME systems can provide 24-hour continuous data sampling and display in a coarse rate, while CAMACs are iteratively operated for finer sampling. The one-shot operation of CAMACs is seldom applied because they have no sampling rate advantage compared to VMEs in long-pulse experiments.

Comparing to the breakless sampling and display provided by the diagnostics control computers, we have to conclude that the cyclic operation between the plural sets of CAMACs would considerably loose the portability of the data acquisition system itself. In addition, the one-shot CAMAC operation for the long-pulse experiment will be seldom applied because they have no sampling rate advantage compared to VMEs. As a result, the LHD data acquisition system will separately allot the fine sampling to CAMACs and coarse sampling to VMEs especially in the long-pulse experiment.

4.1 Long-pulse experiment vs. steady-state operation

In principle, the helical system has an advantage to realize a steady-state plasma operation comparing to the ordinary tokamak system. It is simply because the tokamak is a toroidally current-carrying system and requires the external current-driving mechanism in a steady-state operation where the inductive plasma current becomes useless.

As far as the data acquisition system is concerned, the long-pulse operation and steady-state one are definitely distinguished by means of whether they have a significant time gap in the discharge end or not. The long-pulse experiments have usually enough long a time gap before the next experiment, in which the pre- and post-discharge processing can be executed. The steady-state operation, on the other hand, can be understood as it has less or no time gap to do that. This causes that all of the preprogrammed equipments which will be setup before experiments have to modify their basic idea of usage. It is because the shot-by-shot behavior of the data processing systems will be entirely lost in it.

The device control system like a vacuum gauge controller generally has an ability to work 24-hour continuously as the plant or factory operations. In plasma experiments, for example, the glow discharge cleaning can be usually operated as steady-state. Likewise, the LHD diagnostics control subsystem works under steady-state operation at any time.

As a result, the modification for the steady-state operation is just required for the CAMAC data acquisition subsystem which remains the pulse operational behaviors. The long-pulse experiments of 1 hour can be treated just as an elongation of the plasma duration by databases and storages, while the steady-state plasma operation requires all of the acquisition peripherals from ADCs to storages and even online analytical calculations to have the capabilities of 24-hour continuous plant operation. One of the solution for this problem is to introduce the so-called event-driven data acquisition as mentioned in the following paragraph.

4.2 Event-driven data acquisition method

A demonstration of the new data acquisition system which supersedes the conventional batch-type one has been reported by JET term [5]. It abandons the preprogrammed data acquisition sequence and adopts the event-driven data sampling mechanism, where AD conversions and data transfer are always running and some definite events will execute to copy data from the transient ring-buffer into the storage buffer area. It enables both to pick up the significant transitions and to reduce the meaningless data sampling for the continuous and monotonous phenomena.

Above mentioned concept can be also applied to the ordinary CAMAC ADC by defining some events as its stop trigger [6]. It requires the least modifications to the ordinary CAMAC system, however, the lack of the CAMAC functionality for the simultaneous sampling with data transfer causes the dead time to get and proceed the trigger events.

Regarding with the LHD data processing, its diagnostics control subsystem has already applied the realtime data transfer by using the newly developed reflective memory which synchronize the memory images of both VMEbus and PCI-bus. It is based on the technology of the fast optical linkage "FibreChannel" for the computer peripherals. It seems to be one of the preferable way that we will develop the new CAMAC module of the realtime reflective memory and install as shown in Fig. 2. It will be a simple extension for our VME-PCI system, and also re-utilize the old memoryless ADCs like LeCroy 8210 series.

5. Summary and Discussion

The LHD data processing systems are designed to be fully distributed and functionally separated. They are now under installation for the first plasma experiment in March 1998.

One of their most significant advantage for the long-pulse or steady-state operations seems that they have been split into two major branches of the data acquisition and the diagnostics control. The former provides the functionality of the precise data sampling into the local memory, whereas the latter can execute the realtime monitoring and data transferring continuously. Their behaviors can be easily discriminated as the batch-type shot-by-shot operation and the realtime endless processing. Such a clear separation will realizes the easy modification and also improves the system portability. The extension for the steady-state operation is one of the good case which examines the flexibility of the LHD data processing system.

As a future extension for the event-driven data acquisition system, the extensive application of the reflective memory to the CAMAC is the shortest way to realize in LHD. However, CAMAC ADCs usually apply the stop trigger mechanism and this feature never get rid of the dead time of sampling because after some post-trigger samples they will stop the AD conversion. To investigate the other methods is left for our future research of the steady-state fusion reactors.

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