Diagnostic System Using a Database for High Energy Accelerator Components at the Photon Factory

Noriichi KANAYA, Seiji ASAOKA and Hideki MAEZAWA
Photon Factory
High Energy Accelerator Research Organization (KEK)
1-1, Oho, Tsukuba, 305, Japan

Abstract

A diagnostic system using a commercial database has been designed and built for high energy accelerator components at the Photon Factory, KEK. An operator can choose one or more event items associated with the accelerator components to be inspected. By retrieving any combination of operational information to reproduce the physical behaviors, the system allows diagnosis of the cause of a failure that has occurred at one of the numerous accelerator components, particularly for the twenty-two synchrotron radiation beam lines and the vacuum components of the 2.5 GeV positron storage ring, where X-ray/VUV synchrotron radiation experiments are simultaneously carried out. The total number of items to be inspected by the diagnostic system is over 40 million in order to obtain a correlation between the faulty component and other physical components that would suggest the cause of the failure. With the aid of the diagnostic system, the operator at the control room can easily determine the faulty component, and recover the accelerator component. Experience with the diagnostic system is described.

1 Introduction

High energy accelerators comprise a large number of accelerator components and sensors to be controlled, including digital I/Os and analogue I/Os. The components involve a number of actuators, vacuum valves, cooling-water flow sensors, vacuum sensors, pneumatic-pressure sensors, atmosphere sensors, radiation-safety interlocks, vacuum-pressure gauges and valve-driving units.

A diagnostic system for such complex accelerator components is a key to R&D for the accelerator, providing important trace-back information regarding the physical behavior of its components.

In addition, from the view point of accelerator operations, the diagnostic system must allow the operators to easily diagnose the cause of a failure by retrieving operational information to reproduce the physical behavior that has occurred in the accelerator.

As a template for such components of accelerator complexes, a diagnostic system employing a database management system has been designed and implemented, particularly for synchrotron radiation beam lines. For a large accelerator, a logging system using a database has been also in operation [1].

There are twenty-two synchrotron radiation beam lines at the 2.5-GeV positron storage ring, Photon Factory at the High Energy Accelerator Research Organization. These beam lines feed synchrotron radiation to the experimental hall where experiments, such as surface physics, x-ray lithography, microscopy and crystal structure analysis, are simultaneously carried out. These beam lines are simultaneously in operation, providing intense synchrotron radiation beams. The pressures in the storage ring and the beam lines are maintained at an ultra-high vacuum (UHV) of less than 10^{-10} Torr to achieve a long beam lifetime, typically more than sixty hours.

2 System description

Figure 1 shows a block diagram of the diagnostic System. The database management system employed is Oracle 7. Operational information regarding the beam lines is automatically stored to the Database [2].

These beam lines are automatically controlled by a distributed control system which comprises twenty-two microcomputers and a VAXstation 4000/90, running under VAX/VMS through an optical-fiber network with a star configuration [3,4].

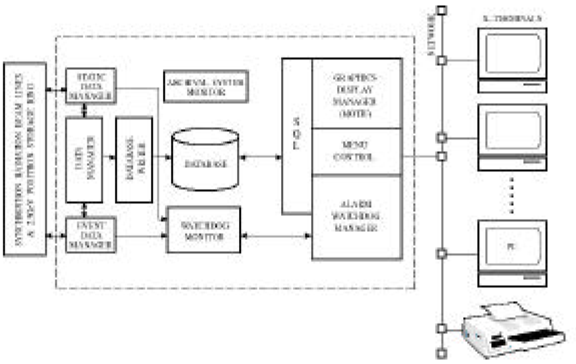

Fig.1 Block diagram of the diagnostic system for high energy accelerator components.

There are two categories of operational data available from the accelerator components: asynchronous event data and static data. The event data is obtained from pick-ups as digital ON/OFF signals generated by vacuum valves, shutters, driving signals for controlling the vacuum valves, and status signals of safety interlock signals. There are approximately 2000 pick-ups in total. Event data is obtained at any instance of time when a component changes its status.

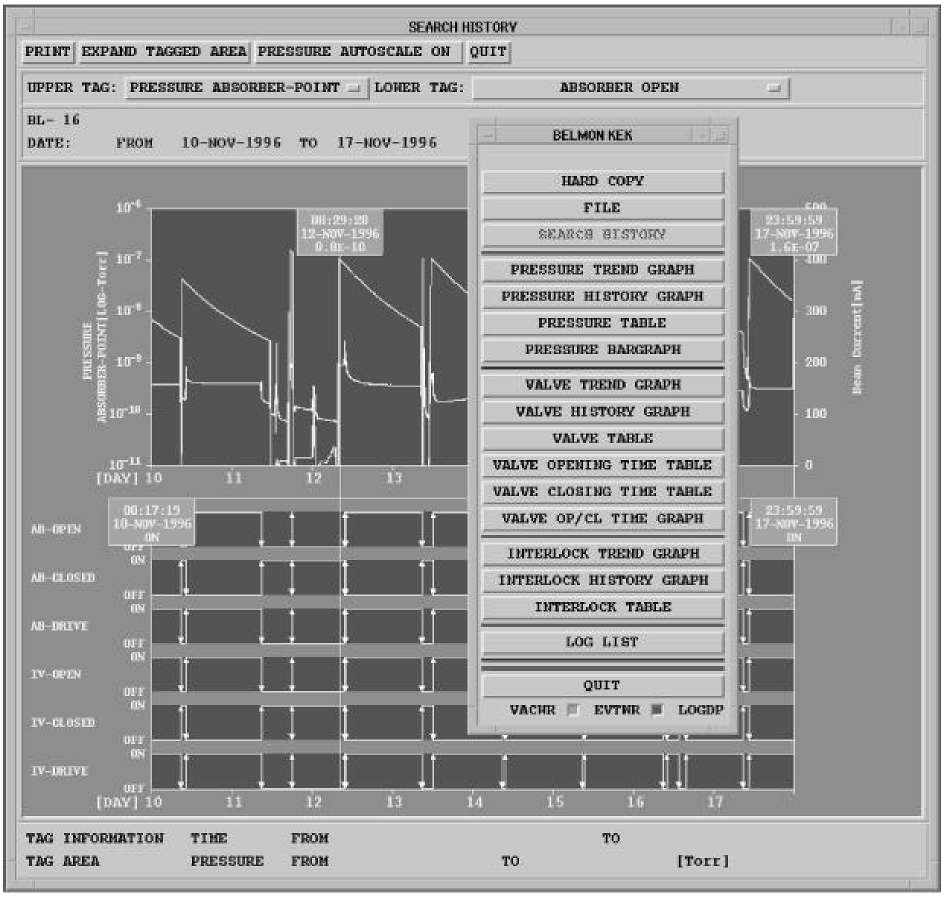

Fig.2 Retrieval result generated by the diagnostic system to inspect whether two accelerator components are functioning properly.

The maximum rate of event signals reaches ~300 events/sec, which occurs at 9AM just before and after the routine procedures for beam injection. The event signals are archived at an accuracy of 20 ms. This also happens when one of the interlocks is triggered in the case that an unexpected failure occurs.

The second category includes static data: static data comprises analogue values that are periodically measured at a specified interval of three seconds. The static data involves a beam current and pressure signals of the storage ring, measured at an interval of three seconds. The total amount data to be stored into the database reaches approximately 40 million items, consuming approximately 2 GB of disk space per year.

The configuration of an accelerator always tends to be modified in accordance with the physics experiments. This leads a new problem: how can we add a new category of a device/ component without adding a row to a table in the database, and keeping compatibility for future modifica-tions of the accelerator. If you add a new row into a table, you must reorganize the data table, and great care must be taken to make it compatible with the existing archived data.

All event data are mapped to a tree data structure with a maxim of seven branch levels, which correspond to the category of devices and components (for examples, a valve category and radiation interlock category). The lowest branch level has leaves, i.e., the status of the component associated with a timestamp. Each level of the tree is mapped to a row of a table in the database, having a unique index, which allows efficient retrieval. This means that the table is normalized to have seven rows plus one row for a timestamp. Adding a new tree (or branch) to the existing tree is done by inserting a new column into the table without the need of reconfiguring the table at all. This does not violate the configuration of the table, indices, and the primary key.

The retrieval viewer is a Motif-based viewer, that provides a full set of menus to allow an operator to choose any combinations of operational data of the components to be retrieved. The retrieval viewer has a SQL query manger that communicates with the Oracle Database using stored-procedures through an SQL-Net driver.

Figure 2 shows an example of how a water-cooled photon mask and an UHV valve are inspected using the diagnostic system, showing the retrieval result of a weekly operation to interpret an unexpected pressure rise in the storage ring. The upper window indicates traces of the beam current and UHV pressures in the 2.5 GeV storage ring and beam line. The lower window is correlated to the upper window area, showing trace-back information of the photon-mask′s status and the vacuum valve, including the status of Open/Close signals and the driver′s signal. Any region on the screen can be panned by dragging the four boxes on the both corners to scrutinize details concerning how these are functioning properly, or to locate a malfunction part.

In addition to the MOTIF viewer, a web viewer is implemented using Java Applet. When there is a failure of an accelerator component during an accelerator operation, the operators can inspect the faulty component of the accelerator and the cause of the failure using an web viewer in order to re-establish accelerator operation. The web viewer then fetches operational information and control data from a remote host computer. Finally, it displays the operational and control information on the WWW browser as the console screen.

3 Conclusion

The diagnostic system using the database for high energy accelerators has been discussed. The system has been shown to be reliable in operation. The system permits failure diagnosis for the numerous accelerator components. The diagnostic system provides valuable information regarding a faulty component and related physical components that would suggest the cause of a failure. By using the diagnostic system, the operator at the control room can easily locate any faulty component, and recover from the accelerator component quickly. This system can be extended for various kinds of accelerator components. The system will be ported to a UNIX platform.

Acknowledgement

The authors wish to express their gratitude to the staff of the Photon Factory Light Source Division for operating the beam liens and the storage ring.

References

[1] R.Billen, “LEP Accelerator Logging System using on-line database”, NIM, Sec. A, pp.296-299, 1994.

[2] N.Kanaya, S.Asaoka and H.Maezawa, “Operational Logging System Using the Database for the Synchrotron Radiation Beam Lines at the Photon Factory”, Proc. of Particle Accelerator Conference 1997, Vancouver, Canada, Mar. 1997 (to be published)

[3] N.Kanaya, “Design of the Distributed Control System for Beam Lines at the Photon Factory”, IEEE Trans. Nucl. Sci.,Vol.NS-31, No.3, pp.957-962, June, 1984.

[4] N.Kanaya, S.Sato, S.Asaoka, T.Koide, H.Maezawa, “Operational Experience with the Distributed Control System for Synchrotron Radiation Beam Lines at the Photon Factory”, Particle Accelerators, Vol.29, pp.227-232, 1990.