DISTRIBUTED CONTROL AND DATA PROCESSING SYSTEM WITH A CENTRALIZED DATABASE FOR A BWR POWER PLANT

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ABSTRACT

Recent digital technics based on remarkable changes of electronics and computer technologies have realized a very wide scale of computer application to a BWR Power Plant control and instrumentation. Multifarious computers, from micro to mega, are introduced separately. And to get better control and instrumentation system performance, hierarchical computer complex system architecture has been developed.

This paper addresses the hierachical computer complex system architecture which enables more efficient introduction of computer systems to a Nuclear Power Plant. Distributed control and processing systems which are the components of the hierarchical computer complex, are described in some detail, and database for the hierarchical computer complex is also discussed.

The hierarchical computer complex system had been developed and now under detail design stage for actual power plant application.

INTRODUCTION

The number of nuclear power generating units and the capacity of generating units are steadily increasing; in consequence, the efficiency of the control, operation and safety of plants urgently needs to be improved.

Under such circumstances, owing to the recent progress of process computer hardware and software technics, the process computer systems introduced in to power plants and becoming increasingly multifarious.

Form the point of view of elevating the level and efficiency of plant operation, the tasks to be accomplished in plants by computers have been readjusted and systematized.

HIERARCHAL COMPUTER COMPLEX (HCC) CONFIGURATION

The HCC is an overall computerized control and instrumentation concept and is based on a systematic analysis of the information concerning BWR power station operation and management. Information and its processing system have been classified into two categories from a functional view point, and three levels dependent on scope. The total system has been designed on the basis that control and processing should be distributed in order to minimize the chance of total system fail. On the other hand information should be centralized to allow manual intervention.

Category 1 is supervisory and control of the plant operation.

Category 2 is data processing and management.

Three levels of the HCC are

(1) Level 1 for power station overall information management involving plueal generating units.
This level is called a site database.

(2) Level 2 for information processing, supervisory and control of the generating unit.
This level is called a·unit level.

(3) Level 3 for local control and data processing which is based on distributed system technique. This level is called a local level.

Relationship between above categories and levels is shown in Figure 1.

Computer systems in BWR based on the HCC concept are shown in Figure 2.

The major components of the HCC are database computers, data communication Networks and specific computers in each level.

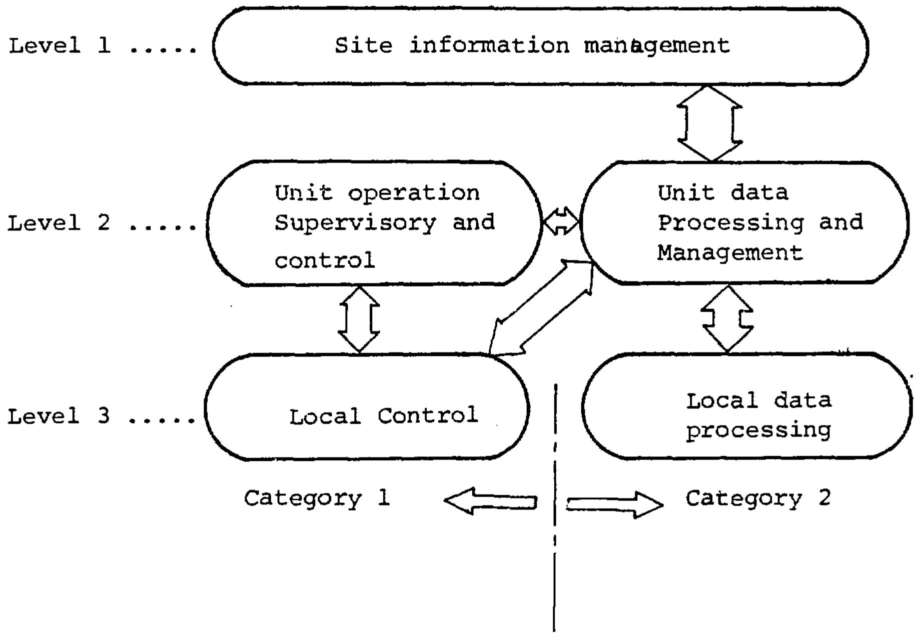

Figure 1 Relationship between categories and levels

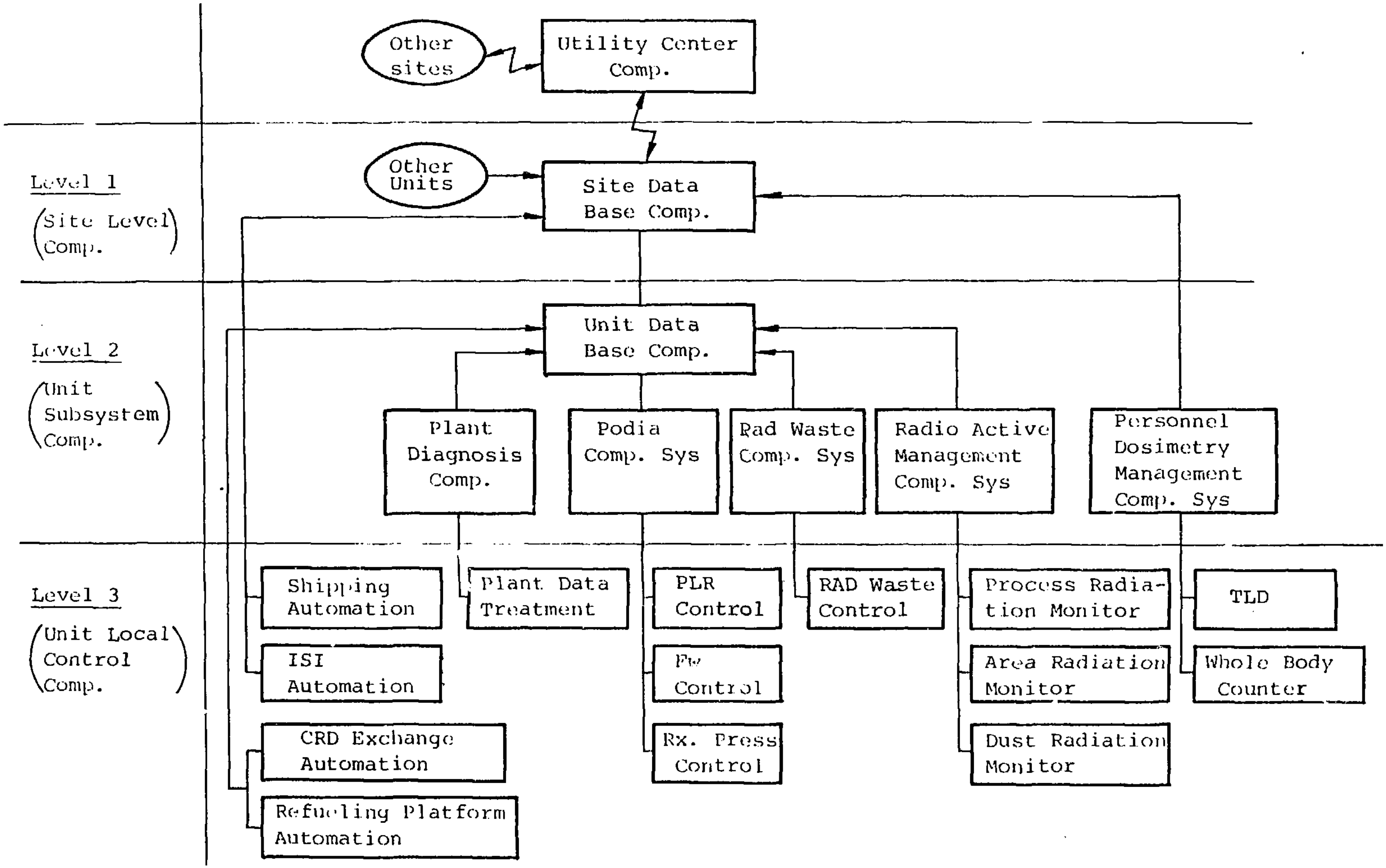

Figure 2 Computer System in BWR

Two major data highway loops are provided in the HCC, viz. site loop and unit loop. The unit data highway loop interconnects level 2 computers and transmits data from the operating plant to the unit database computer. The site data highway loop interconnects unit database computers and transmits data from unit database computers to the site database computer. Configuration of the HCC is shown in Figure 3.

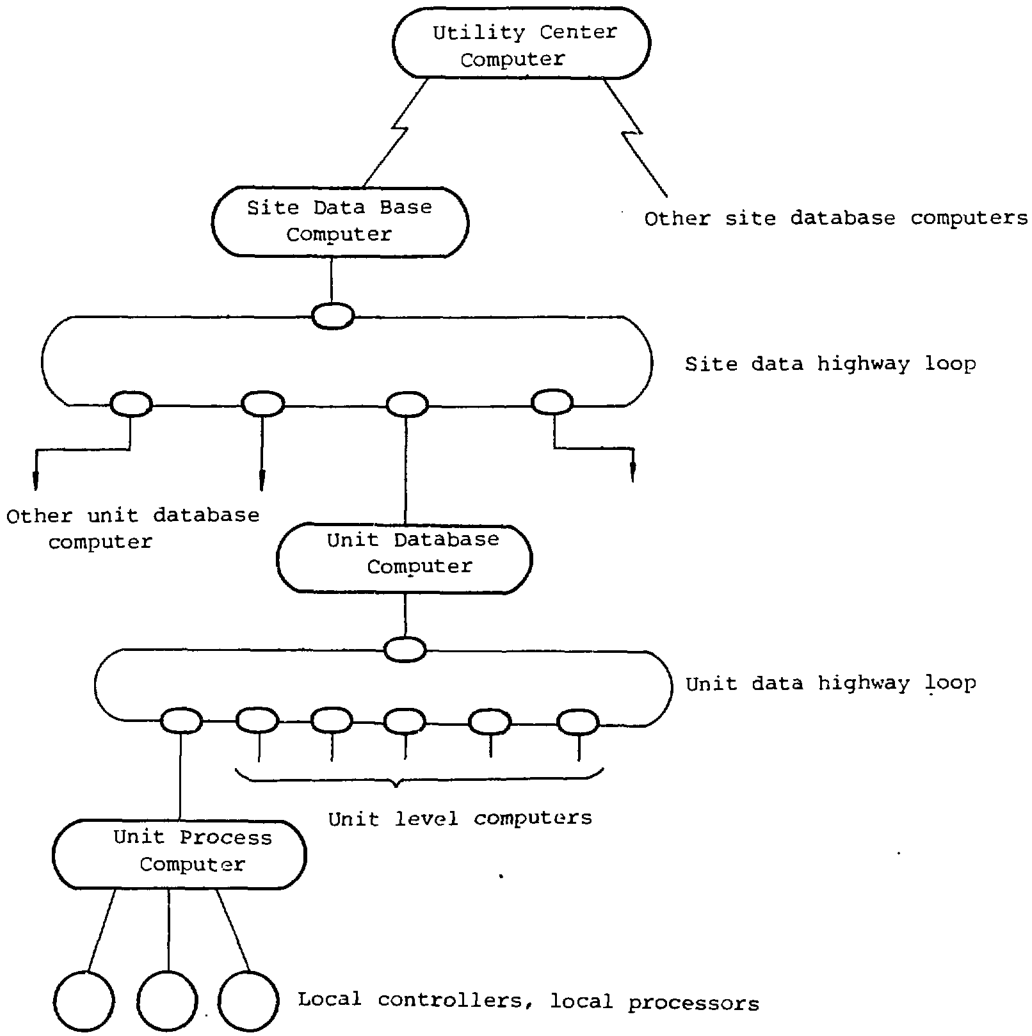

Figure 3 Configuration of Hierorchical Computer Complex

The Level-1 Function

The Level-1 computer system is interconnected to each Unit database computer in Level-2 through a communication line. This computer system accumulates the unit data sent from the Level-2 computer systems, so that the Station database (Site database) is formed.

The major items of the Site database are as follows.

(1) Operating data commonly used by each unit.

(2) Plant operating historical records over a long period.

(3) Personnel dosimetry monitoring data.

(4) Radiation monitoring data.

(5) Fuel istopic data.

(6) Maintenance management data.

(7) Site environmental data.

(8) Spare parts stock data.

(9) Nucleus material library.

The Level-1 computer system performs the following functions.

(1) Plant operation management.

(2) Security Management.

(3) Maintenance Management.

(4) Communication with head office.

Plant operation management

The control rod patterns are usually exchanged every few months to attain the desired fuel exposure distribution. A reactor simulation program makes a prediction of the long-term fuel exposure, and reactivity change rate, which provides the plant manager with the capability of planning the changes in the control rod pattern. The Level-1 computer system can offer past, present and future operating data in order to maintain optimum operations.

Security management

In order to reduce the personal dose, it is necessary to monitor the personnel dosimetry throughout the working hours and work area. Personnel dosimetry monitoring is a slow laborious, routine task, the computer assists in such a routine task by acquiring several types of personnel dose data via the Level-2 computer system, and storing them in the Site database. The dose data can then be printed out and/or displayed for each person individuallly, on request.

On the other hand, the Level-1 computer system records and monitors area radiation, process radiation, process discharges and environmental conditions in many locations, both inside and outside the BWR Power Station. This radiation monitoring data is verified tc maintain the environmental conditions in their correct range.

Maintenance management

Routine maintenance is conducted in accordance with the specified procedures, to reduce the possibility of error disturbance to the components. It is essential that the component and system maintenance records are properly maintained, to facilitate the scheduling and completion of all the necessary maintenance. The computer performs the schedule reporting of the necessary maintenance and testing, and spare parts stock management, in support of the routine maintenance.

Nonroutine maintenance is scheduled as necessary during periodic shutdowns of the unit. Some examples are, refueling (;exchanging the fuel assembly), control rod replacement, control rod drive mechanism removal and replacement. The computer memorizes the component histories and lists all necessary replacements of the components.

Communication with the Head Office

The Level-1 computer system can communicate with the Head Office through a communication line such as a telephone line. Economic load dispatching can be achieved by receiving the load schedule, from the Head Office to the Station, via a communication line. The Level-1 computer system can perform load calculation and dispatch the unit schedules.

The Level-2 Functions

The Level-2 system, (computer complex), consists of the following;

(1) Unit database computer system.

(2) PODIA (Plant Operation by Displayed Information and Automation) system.

(3) R/W (Radioactive Waste Treatment) supervisory computer system.

(4) RPDM (Radiation and Personnel Dosimetry Monitoring) system.

Unit database computer system

The Unit database computer system gathers the unit operation real time data from the other Level-2 computer systems, then handles and transmits it to the Level-1 computer system. The unit database is a part of the Site database, which is especially concerned with the respective unit operation data.
This system controls the communications between the Level-2 systems when accessing the unit database.

PODIA system

The main objectives of the PODIA system are to provide an effective aid for the monitoring, control and operation of the unit. The PODIA system performs an important role in unit operations. The main interface between the Operator and the Plant is a computerized and miniaturized PODIA console (Advanced Operator Plant Interface), located in the central control room. The unit operating data including the status, value and alarms, is displayed on color CRTs in graphic display formats. In the PODIA system, the hardware display devices (i.e. meters, indicators, recorders, etc.) on a conventional operating berchboard are replaced by color CRT graphic displays.

Switches and control devices are fully miniatuarized, and their number reduced by computerized automation. Therefore, the PODIA console is much more compact in contrast to the conventional operating benchboard.

(about one third)

R/W supervisory system

The objectives of this system are to monitor the liquid and solid waste treatment system components.

In this system, hardware mimic display panels are replaced by the full color CRT graphic displays, so that this system console is more compact in size than a conventional R/W operating board. The computer system conducts the detailed historical data logging and liquid waste mass balance calculations.

RPDM system

The major functions of the RPDM system are the monitoring and recording of the process radiation, area radiation and liquid and gaseous radiation. Another function of the RPDM system is the personnel dosimetry monitoring, which relieves the staff in charge of radiation protection, of the burden of laborious and time-consuming routine work.

Level-3 Function

Local control and data processing computers based on the distributed system technique have been widely introduced into BWR Power Plant.
Examples of the Level-3 are;

(1) Digital controllers for power control.
(2) Programmable logic sequence controllers for Rad/ Waste control.
(3) Refueling platform automation.
(4) Control rod drive mechanism exchange automation.
(5) Dosimeter reader controller.
(6) Pre-processing of the signals for plant diagnosis system.
(7) Reactor power program controller.

Digital Controllers for BWR Power Plant control

Digital Controllers, one of the typical application example of a distributed control system, which utilizes 16 bits micro-processors has been developed to control BWR major control systems, such as primary recirculation control system, reactor pressure control system and feed water control system.

In general, digital controllers consisting of micro-processors have numerous advantages in comperison with analog controllers.

These are;

a. Separation of function and hardware
b. Easiness to standardize and modularize hardware
c. Flexibility to change, add or delete
d. Capability of complex arithmetic and logical functions
e. High reliability and maintainability

TOSHIBA has developed micro-processor application study and applied it to the primary recirculation control system, reactor pressure control system and feed water control system.

Figure-4 shows the system configuration of digital controllers for the power control system.

The digital controller consists primarily of CPU (Central Processor Unit), memory, and process I/O interface.

Hardware specification

CPU	Execution time	2.1 μs
	Instruction word	16 bits/32 bits
	I/O transfer rate	38 Kbytes/sec
	Micro program control	
Memory	Magnetic core	16 bits + 1 parity
	Cycle time	800 nsec
	Capacity	32 Kbytes
Process I/O Interface	High Speed Analog Input	Sign + 11 bits
	Normal Sample Mode	20 ∿ 25 μs
	High Speed Analog Output	Sign + 11 bits
	Speed	10 μs
	Digital Input/Output	

The system performance is demonstrated utilizing the hybrid computer. (Simulation Test)

System performance is demonstrated as follows:

a. Basic control performance

b. Demonstration of the capability to improve and evolve

for example

- Reactor water level setdown function on turbine trip or reactor scram
- Recirculation pump runback for a feedwater pump trip

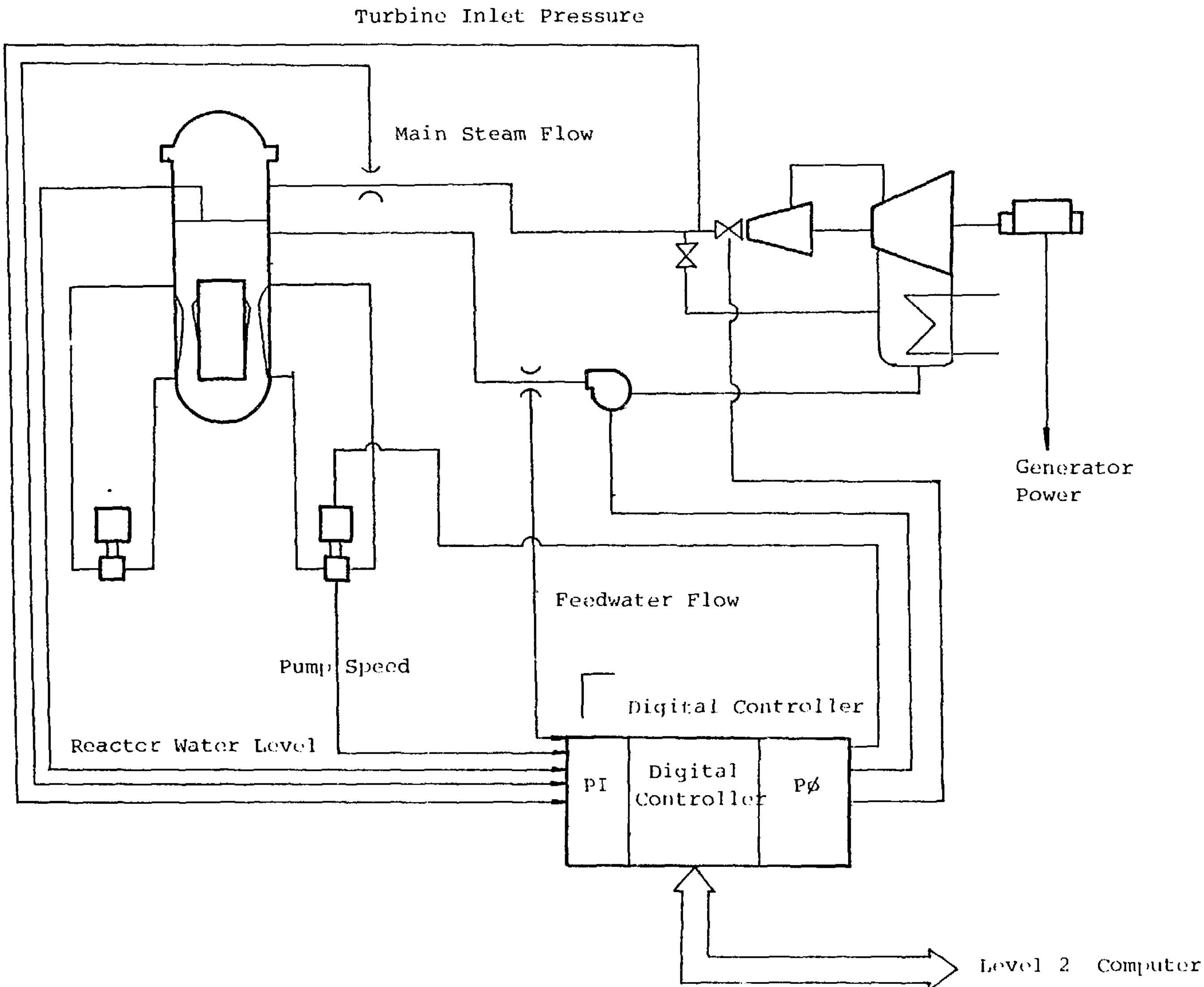

Figure 4 Digital Controller for Power Control System

It is confirmed through the simulation test that the control performance of the conventional analog controller can be realized by the digital controller and that the digital controller, has the capability to add, improve, and evolve plant control function satisfactorily.

Sequence Controller

Process control functions in nuclear power plant are becoming more and more complicated in order to attain safe and reliable system conditions.
These complicated control functions cause an increase in the number of components, such as relays, contactors and wiring.
Therefore, the availability and reliability of these control circuits is decreasing in proportion to the increase in the number of components.

TOSHIBA has developed a compact, highly reliable sequence controller for application in a nuclear power plant.
Sequence controller logics are stored into the memory and controlled by the control program.

Control processor is 16 or 12 bits LSI.
An actual application in a nuclear power plant is in the radio active waste system.

The reason why radio active waste system application is selected is that this system is a more complicated function and the system scale is very wide.

By application of the sequence controllers to a radio-active waste system, the total control panel length is reduced to almost one-second of the conventional control panel.

The sequence controller also has a data processing function in order to transmit process data to an upper level supervisory process computer.

COMMUNICATION NETWORK AND DATABASE

To achieve optimum system performance 2 merits and demerits of the distributed and/or centralized system have been studied. Major components of the distributed system, viz. database, communication method and processing modules, had the key to system performance, therefore they have to be selected for optimum performance. Computer systems in each level described above, are examples of processing modules.

A communication network is essential to the distributed system to attain the centralized supervisory information system. To reduce the plant operator's burden, information of the plant operation has to be gathered and prepared ready for use. Performance of the communication network is shown in Table 1 as an example.

A nuclear power plant involves a very large scale and complicated process, therefore database of plant operation and management is utilized not only for

No. of station	64
Communication Speed	10 Mega bps
Connection	Duplicated Loops
Distance between station	4 kilo meters
Maximum loops length	100 kilo meters

Table 1: Performance of Communication Line

daily plant operation, but also security control and plant maintenance.

A nuclear power plant is so complicated and data is so interrelated that a centralized database system have been adopted rather than a distributed database. Capacity of the database is more than 300 Mega Bytes.

CONCLUSION

Computer based, totally integrated digital control and monitoring systems have been developed, and distributed systems are introduced as a local level. It is expected that this trend towards the digitalization of control and instrumentation will become more common.

Then, problem to determine a reasonable devision between hardwired and softwored systems will need to be studied.

Micro-processors have realized the distributed system but emergence of high performance mini computers, called super-mini, provided a chance to introduce a site specific information management computer within reasonable cost. Hence, it is necessary to study a total system involving both distributed and centralized systems.

Further study will be made to include a remote multiplexing system which will be classified below level 3, say to level 4, to improve reliability, availability and maintainability of a nuclear power plant.

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