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PLANT INFORMATION NETWORKS

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1. Concept of a Computer Network Architecture for Complete Automation of Nuclear Power Plants, *Robert M. Edwards, Asok Ray (Penn State)*

INTRODUCTION

The state of the art in automation of nuclear power plants has been largely limited to computerized data acquisition, monitoring, display, and recording of process signals.[1] Complete automation of nuclear power plants, which would include plant operations, control, and management, fault diagnosis, and system reconfiguration with efficient and reliable man/machine interactions, has been projected as a realistic goal.[2] This paper presents the concept of a computer network architecture that would use a high-speed optical data highway to integrate diverse, interacting, and spatially distributed functions that are essential for a fully automated nuclear power plant.

SUMMARY

In our previous publication,[3] the concept of integrated control in nuclear power plants was projected to be hierarchical at the supervisory, subsystem, and component levels with the objective of meeting power generation, plant protection, and safety requirements. Such a control system is merely one of the major ingredients of a completely automated nuclear power plant. The required functions are typically viewed as isolated entities that are to be integrated by human actions. These functions, in addition to plant control, could be classified into the four broad categories of diagnosis, monitoring, operations management, and engineering analysis, as illustrated in Fig. 1:

1. Diagnosis includes analysis of plant data to identify problems in plant operations and the steps needed to resolve these problems.

2. Monitoring includes (a) checking that the technical specifications and regulatory guidelines of individual equipment are and will be met and (b) collection of duty-cycle data, such as those to support fuel burnup calculations.

3. Operations management includes production, maintenance, and refueling outage scheduling, personnel management, procedure tracking, and the inevitable resolution of conflicts that arise in these activities.

4. Engineering analysis refers to (a) those other than duty-cycle data analysis, such as results from periodic inspections and special measurements (e.g., nondestructive testing), and (b) preparation of drawings and records that reflect the current "as-built and updated" configuration of the plant.

A configuration to accomplish any one of the above five functions can be hierarchically structured involving multiple computers and a communications network that would interconnect the subsystem components and interface with other networks.[4,5] Incorporation of all five functions within a hardware-oriented communication structure (e.g., point-to-point dedicated connections) may fail to achieve the desired goal of complete automation. The rationale is that the same information is often repetitiously needed for executing different functions and it is not practical to provide separate access to each device and instrument in the plant. Therefore, the information base must be shared via a multiple-access common network medium. For example, analytic redundancy[6] and other signal validation[7] information could be shared by several noncollocated functions for fault diagnosis. Similarly, other functions, such as engineering data, management decisions, monitored data, and current control performance, must share a distributed information base.

In such a distributed information-processing environment, interfacing of independent networks via bridges and routers are potential bottlenecks. This difficulty can be alleviated by use of the advanced computer networking architectures that are emerging in aerospace[8,9] and manufacturing[9,10] technology. Specifically, in aerospace applications, the concept of a vehicle management system encompasses integration of real-time flight-critical (e.g., structural, aerodynamic, propulsion, and air data sensing) functions with avionics (e.g., mission, weapons, and flight management) functions over a high-speed (100 Mbyte/s or higher) optical fiber network. The concept is analogous to that of interfacing integrated control[3] of the nuclear steam supply system and balance of plant and with other operational and management functions that are outlined in Fig. 1 for complete automation of nuclear power plants. This ensemble of time-critical and non-time-critical functions can be viewed as an interactive multiloop control system where the term "control" is not restricted to conventional feedback systems but also includes man/machine interfaces and human decision processes in the loop.

As a first step in developing and demonstrating the control architecture of Fig. 1, integrated plant subsystems and control modules have been simulated in real time.[11] A recently completed research project[12] demonstrated simulation and plant testing of a diagnostic expert system that can be extended to research in a distributed environment. Other research projects have been initiated by the U.S. Department of Energy and more recently by the National Science Foundation for analysis, design, and implementation of integrated control and diagnostic functions at the Experimental Breeder Reactor II (EBR-II) and at the Intelligent Distributed Controls Research Laboratory of Pennsylvania State University, which will have a Bailey NETWORK-90 control system compatible with EBR-II and other networks and computer facilities. The remaining three functions are envisioned to be implemented in separate computer systems. A subset of these functions is likely to be hosted in the controllers that are served by the network. The ultimate goal of this research is to develop an interactive multiloop control system that is served by a single high-speed optical data highway, as shown in Fig. 1. Advances in fiber optic technology are expected to achieve a transmission speed of 1 Gbyte/s within this century. This speed should accommodate all essential functions within the single network of a completely automated nuclear power plant. Under all circumstances, such a network must be designed with redundant buses and guarded against all single-point failures (and possibly multiple failures for the critical and safety-related functions).

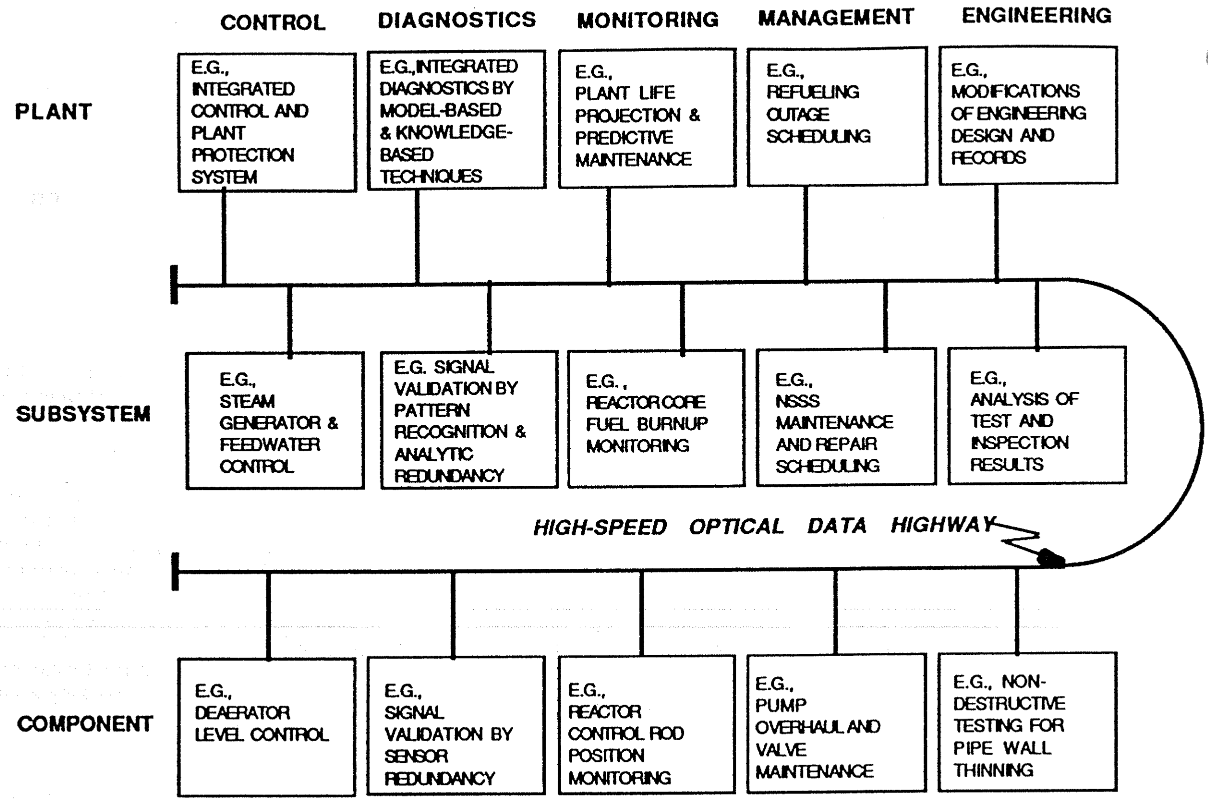

Fig. 1. Schematic representation of completely automated nuclear power plant functions on a high-speed optical data highway.

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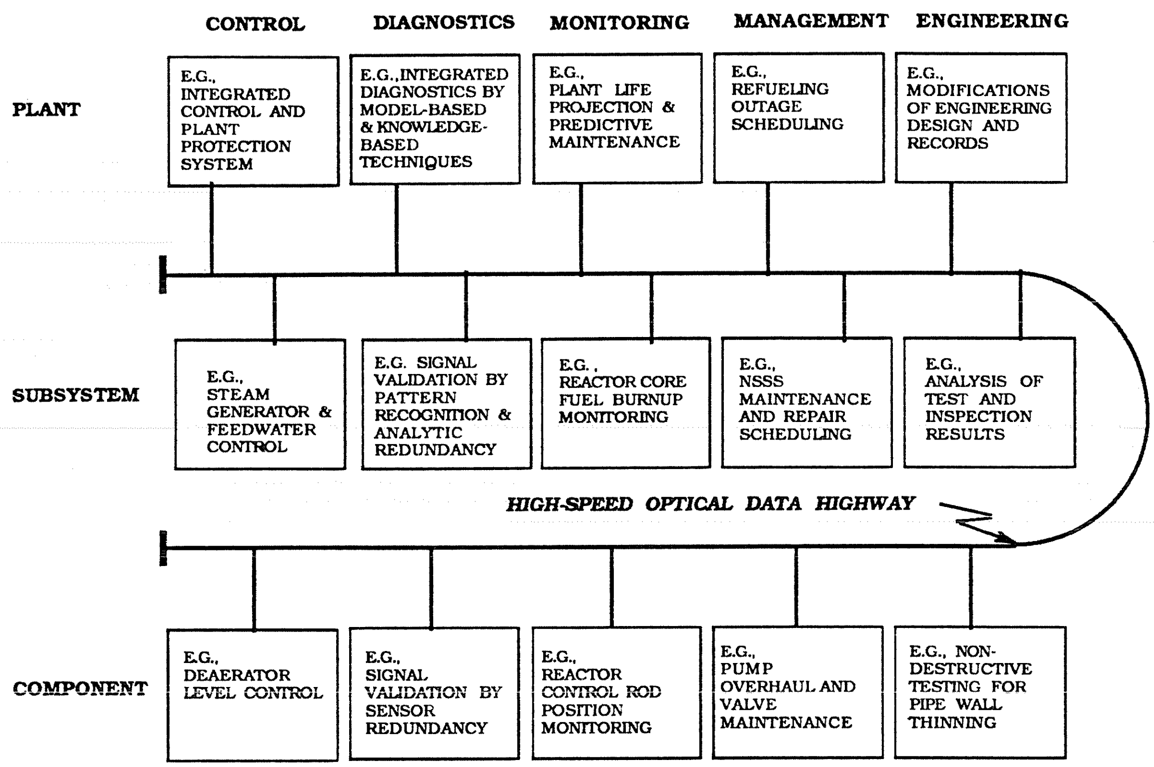

FIGURE 1: SCHEMATIC REPRESENTATION OF COMPLETELY AUTOMATED NUCLEAR POWER PLANT FUNCTIONS ON A HIGH-SPEED OPTICAL DATA HIGHWAY