MODERN POWER PLANT CONTROL PHILOSOPHIES

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ABSTRACT

The architecture of today's microprocessor-based distributed control and data acquisition systems allows integration, control and monitoring of various plant control systems from a centralized operator interface. This paper describes the conclusions of the authors resulted from studying of many Distributed Control System documentation and the approach used in establishing the design of DCS implementation in several romanian Power Plants. Key aspects associated with the control system architecture, integration with plant control systems, and graphical operator interface are investigated. This paper also summarizes future trends expected in this area of control and monitoring integration technology based on this experience.

KEYWORDS: Distributed Control Systems, Control Philosophies, Integration

INTRODUCTION

Today's microprocessor-based distributed control system (DCS) allow implementation and integration of various plant controls. These systems allow the coordination of plant control and monitoring functions from a centralized operator interface. Also these systems allow new power plant control philosophies to be established which are dependent upon reability, operability, maintainability, and economic factors. Power plant control concepts are not constrained, as in the past, by the application of today's control system technology. This paper looks at new power plant control designs possible with today's technology, investigates the potential designs of plant-wide control system integration, suggests alternatives that can improve the reliability of the design, and reviews the type and format of information required by the plant operator. This paper also describes the design approach, review, and implementation process that are utilized in developing a plant-wide integrated control system within the economic constraints of today's projects. Future trends expected in this area of control and monitoring integration technology are also summarized.

DCS CONCEPT

A DCS offers effective solutions for the main aspects of automation:

- Process control - with a range of controllers, ranging from a small PLC units to advanced controllers for logic and regulatory control.
- Operator interaction - by means of man-machine interfacing equipment, ranging from low-cost, monochrome video terminals, to advanced operator stations featuring the latest technology in user interfacing: high-resolution color graphics and windowing based on industry standards, such as X Window System.
- Engineering - is supported by engineering stations and software packages for tasks such as configuration, documentation and fault tracking. Off-line engineering as well as on-line configuration are supported.
- Information management - is supported by powerful functions providing the right information for decision-making. An open platform allows for inclusion of standard for production planning, optimizing control, or administration.
- Communication - features fieldbuses as well as wide and local area networks, with a set of data links, and communication stations for connection to external computers and communication networks, as well as connecting control networks to the plant network.

The following key words sumarize the DCS philosophy:

- Integration - functional, structural and informational integration.
- Distribution - the system consists of controllers, OS/ES stations and IMS stations. The real -time process dadabase is entirely distributed to the controllers. These are functionally complete and able to perform logic control, regulatory control and advanced calculations. The control system can be structured according to the process requirements without restrictions imposed by limitations in the control system. Geographical distribution is catered for by a fieldbus, to which distributed I/O units,

controllers and variable-speed drives can be connected. In order to extend the control network over long distances, communication bridges, radio links and even satellites can be employed.

- Reliability - in some cases, extremely high availability is required in parts of, or the entire control system. To meet such requirements, critical parts at all levels can be duplicated.
- Openness - the use of open technology and standards such as: SQL, X Window System, DDE.
- Investment Security and Expandability - the first step may involve control of single machines and process sections. The next step may be to conect the separate control systems to a communication system and to add functions for joint control. A final step might be to introduce central rooms with advanced operator stations, and perhaps even to connect several, separate control systems into a plant-wide network.
- System Upgrades - Both the hardware and software of DCS are continually updated with new features and functions to keep it on the leading edge of technology. New capabilities are offered to existing users in the form of an upgrade to bring the installed system up to the latest version available.
- Compatibility Policy - products of different releases, within the same control network as well as between separate control networks, will be able to communicate with each other. Application software will be possible to transfer from older version to newer version with a minimum of manual work.

PLANT OPERATION

The DCS includes a unit master control panel that allows the operator to select manual, boiler follow, turbine follow, coordinated, load control, and turbine bypass control modes. The operator can manually set load demand, maximun and minimum load limits, and load demand rate of change, as well as select the various unit operating modes. Displays of the unit load demand and actual unit load generation are provided. The load demand for the unit is either set by the operator manually or by the SCADA control system.

The plant can run back to minimum boiler continuous stable load from full - or partial-load conditions and maintain plant auxiliary load requirements. In many romanian power plants the existing control room includes the following equipment:

- a modular desk, allowing the unit monitoring, using signalling tiles and analogue indicators and unit operating through dedicated individual control tiles for open loop control and closed loop control

- conventional panels with recorders and indicators for 4-20 mA signals or direct connected thermoelements and thermoresistors.

FUNCTIONS AND ARCHITECTURE FOR DCS

Functions

The DCS is a fully integrated, microprocessor-based, distributed control system, which serves as the main plant control and data acquisition system. Acording to the international concepts the DCS must fullfill the following functions [1]:

- operative functions: operating, monitoring, closed loop control, open loop control, protection, operating guide

- quasi-operative functions: configuring, diagnosis, maintenance

- non-operative functions: engineering (including docummentation), logging (protocols), archiving.

The DCS performs the following functions:

- boiler control
- burner management
- motor and solenoid valve control
- boiler, turbine-generator, and balance-of-plant data acquisition
- based alarming
- logging, including sequence of events
- historical storage

In most of the cases there are control systems which are delivered by the supplier or are realised with PLCs.

The DCS interfaces with these control systems to allow main control room operator control and monitoring of the respective systems:

- turbine EHC system
- sootblower control system
- coal handling system
- wastewater treatment system

Architecture

The DCS architcture consist of a redundant data highway with ‘drops’ connected to it that perform specific functions. These drops are located in the electrical equipment room, main control room, or computer room, depending on function. The functionally distributed and redundant processing units (DPUs) are centrally located in the electrical equipment room, each unit is programmed to perform specific tasks for the plant control and data acquisition applications assigned to it. Operator interface to the system is via VDU and keyboard operator consoles located in the main control room with limited hardwired backup provided.

The DCS interfaces with several personal-computer-based plant monitoring systems to allow importing of status and alarm information from the DCS to the plant monitoring system:

- Unit efficiency monitoring system
- Chemical Analysis Monitor

The DCS is furnished with the main control console center located in the main control room. Touchscreen function is used to select an item on the screen. Each operator console contains battery-backed random-access memory (RAM) for storage of the graphics. Each console can access and control all plant functions; however, dedicated graphics are

preprogramed at each console. The engineer's console provides all software engineering tools and hardware devices required to configure and maintain the DCS program.
The logger drop collects, formats, and prints process data in custom periodic, trip, and sequence-of-events logs. The historical storage drop collects process data from the data highway for trending and transfers the information to the magnetic tape unit for long term storage.
The universal programmable controller interface (UCPI) is a programmable protocol gateway that networks host programmable controller-based plant control systems to the DCS data highway. The station interfaceunit (SIU) is a programmable protocol gateway, similar to the UPCI; however, it networks non-PLC host devices to the DCS data highway.
Power Plant Control philosophy provide two architectural concepts: "athomic" and "molecular". We use the "athomic" concept in the situation of Turbine control and "molecular" concept in the case of control functions achieved by DPU and PLC. It is important to use the "atomic" concept in case of control critical systems from the response time point of view.
A block diagram of the DCS is represented in Figure 1.

DPU functional partittioning

To maximize the capability of the DCS DPUs and enhance the reliability of the control system, control and data acquisition functions performed by the DCS were distributed among several DPUs.
It controls were partitioning by first defining the control loops and services to be controlled by the DCS. Logical control groups were then developed, based on plant control application and the design of the mechanical system.

Alarming

The DCS is the primary system for monitoring plant process variables and conditions and for alarming abnormal situations. As a backup system to the DCS, a hardwired visual annunciator system is provided. All DCS alarms are assigned a priority level from 0 to 3 based on their critically to the process and the required operator reaction time to alarm. Annunciator inputs are derived from independent field contacts or DCS generated digital outputs. If derived from a field contact a parallel field is monitored by the DCS.

COMPLEX ADAPTIVE SYSTEMS AS MODELS FOR DISTRIBUTED CONTROL

Recently, the succes of Complex Adaptive Systems (CAS) researchers in using intelligent agent simulations, with some form of self-modifiability, to model natural processes has led engineers to apply these same methods to the control of manmade systems whose complexity would otherwise lead to exponentially increasing computational demands. The simplest kind of DCS would combine remote sensors and actuators to form regulators, and adjust their set points or biases with signals from a central location. Replacing the regulators with conventional feedback or PID controllers can improve their response to changing local conditions, but as these distributed controllers increase in number or the interaction among their functions intensifies, it becomes extremely difficult to supervise and coordinate their switching points.
As complexity increase and decision-making approaches real-time, the computational burden on the central computer increase, until massively parallel processing is required. But even before this point is reached, there can be a significant benefit in distributing both the computational load and the detailed decision-making among the local sensors and actuators, which have both the data and the ability to act on it. Mathematical and computational techniques of CAS provide new tools for the engineering design of distributed control so that both centralized decision-making and the communication burden it creates can be minimized. The basic approach to analyzing a CAS is to model its components as independent adaptive "agents" – partly cooperating and partly competing with each other in their local operations while pursuing global set by a minimal supervisory function.
The study has found that, given the capability for merely rudimentary intelligent behavior, the agent will self – organize in a way that benefits the CAS even as it benefits them individualy [3]. To use this method for DCS of a complex plant system, the designer (1) creates a "fitness function" for the agents that represents required goals and constraints for the plant being controlled, and (2) includes in the design of the agents themselves a sufficient variety of resources and strategies from which they can select combinations to use that plant even as the uncontrollable parameters affecting the plant change.
The agents "evolve" by "adapting" their behavior in both competitive and cooperative ways to meet general goals which are assigned by the designer but whose details may also change through the same "evolutionary" process [3].
In the context of a DCS , each individual agent represents a local controller, comprising one or more sensors and/or actuators, a microprocessor with some memory and two-way communications. This configuratioon could be created by adding some computational power to what would otherwise be a simple regulator or a PID controller with remotely adjustable bias, set point and/or gain.
Conceptually, the added computational power would came from the distribution of the processors and the memory in a central computer made up parallel processor [2].
It is better to design a control system that can adapt its own behavior reasonably and safety, if not always optimally. Given the time to act, experienced human operators do this remarcably well. Distributed intelligent control with adaptive agents can provide the same robust response to as fast-changing process in real-time.

PLANT CONTROL SYSTEM DESIGN PHILOSOPHY

Initially all plant systems were reviewed from (1) type of control system, (2) method of primary control and logic implementation, (3) type of operator interface and (4) application and degree of local control capability.
For each plant system, the type of control system to be utilized was determined based on the control logic requirements of the system and the location of the primary control system operator interface [1].
Several scenarios are possible:

- DCS control and DCS VDU- operator interface
- Non-PLC control system and DCS VDU operator interface
- PLC control and DCS VDU operator interface
- PLC control and DCS/local VDU operator interface
- PLC control and local VDU/control panel operator interface.

For example, all boiler control, burner management and digital controls can be designated to be performed by DCS. Several plant systems such sootblowing system, coal handling and wastewater tretment system utilize PLC control. The sequential digital logic, normally required for these systems, is well suited for PLC control, and be economically advantageous over DCS.

PLANT CONTROL SYSTEM AND DCS INTERFACE

To provide the operator with control and monitoring capability for system that utilized control system independent of the DCS, datalinks were established between the DCS and host control systems. The datalink gateway to the DCS was configured using the universal programmable control interface (UPCI) or the station interface unit (SIU) drop as described previously. Process values and messages from the host system and those developed by the DCS for transfer to the host device are presented as operating information for display on DCS OS/ES stations. The UPCI turns the existing host data acquisition, or process device into a DCS drop. Any data value originated by the host device can be selected to be broadcast over the DCS data highway. We notice at the communication level the tendency of using different buses under a common standard: in the case of fieldbus – PROFIBUS, and in the case of Plant Network – ETHERNET.

Turbine - EHC
The turbine EHC is an example of an non-PLC control system connected to the DCS as shown in Figure 2. The primary purpose of establishing this datalink was to graphically emulate the EHC control panel installed on the main control console center. Turbine control via DCS operator stations was deemed necessary to maintain the integrated plant control philosophy.
The DCS performs all the turbine prestart check logic before allowing the turbine ECH to initiate the auto startup mode.

Coal Handling
The coal handling system are controlled by PLC. Coal handling conists of transporting from the coal pile to the coal crushers and transport to the coal silos in the boiler room. Control of coal handling is not considered the responsibility of the main control room operator, and therefore, only local control of this system is provided. Figure 3.

Sootblowing System
The sootblowing system is controlled by a PLC, which is located, together with the PLC I/O rack, in the plant electrical equipment room.

Water Treatment System
One last example of control systems integration consists of processes that are controlled only at the equipment. The condensate polisher and makeup demineralizer are PLC systems with local operator consoles as shown in Figure 4.

GRAPHICAL OPERATOR INTERFACE DESIGN

The design, configuration, and testing of DCS graphic displays were considered the most important design of the DCS. The design process for the DCS graphic displays included the following steps:

- organize plant systems into groups and subgroups
- develop initial plant system envelopes and display layouts
- apply preapproved design concepts to develop complete and coded graphics
- configure and test graphics using an actual database.

GRAPHIC DISPLAY DESIGN
Standardized design concepts has to be developed before starting the graphic displays. The design criteria established uniformity in the format of the graphic. The more important aspects of graphic display design are described below:

- screen organisation - the basic screen is subdivided into two regions: the main screen and the subscreen (with information or messages such alarms)
- process value display - represented both quantitatively and qualitatively.
- color coding - were used to separate esential (device status or parameter) and nonesentialy (static devices) information.

FUTURE TRENDS

The design of a DCS system is influenced by the following factors:

- plant operating procedures
- reability issues
- project cost factors
- state-of-the-art technologies.

In applying these state-of-the-art design to the plant control system, reliability of the design is of major concern and steps were taken to ensure that the plant availability will not be compromised.

As with any new design, maintaing project costs within the established engineering, design, construction, and testing budges are also importance. Using CAS as models for DCS would allow a fully automated management of future power plant in real time.

CONSIDERATIONS

This concept of control system is a forward step in the design of integrated plant control systems. This concept is based on the authors experience in studying, design and implementation of several DCS. A vision of future trends in power plant control system design can be described by reviewing the following issues:

- plant control system integration - the ideal power plant control and information system design is to connect all plant systems to a common data highway. With the establishment of a global database, all plant operation and maintenance can be performed from elements connected to this data highway
- microprocessor PLC system - PLC will continue to perform plant control functions for specific functions where PLCs are most beneficial. These include systems that are sequentially controlled and operated (digital logic) and have minimal requirements for modulating control and analog process measurements.
- geographical distribution of Processor/remote I/O - placing the control processors and/or I/O within the plant at the process to minimize cabling is a cost-effective approach and is now a common design practice.
- operator interface design - OS stations will improve with graphic capabilities with expanding technologies in VDU design.
- advanced control technologies - such multivariable control algorithms, self-tuning controllers and integration of diagnostics and predictive maintenenance information are presently being used and will continue to be practical, considerations in the future distributed control system design.
- in combination with explorations of intelligent sensors and fast control devices, a fully automated management of power plant in real time could be provide. This system will be:

- measured by localy authonomous intelligent sensors
- modeled as a hierarchy of competing and cooperating adaptive agents
- computing in parallel, distributed in space
- autoomatically controlling local operations, guided by global optimization criteria.

Fig. 1 - Distributed Control System Block Diagram

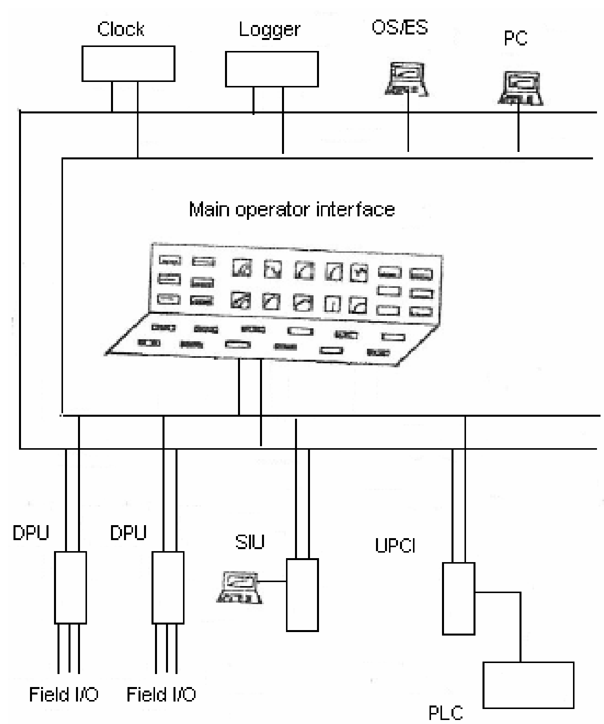
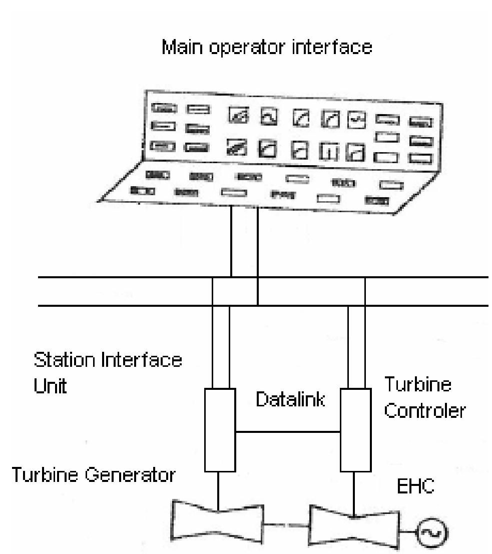


Fig. 2. - Non-PLC Control System and DCS Operator Interface



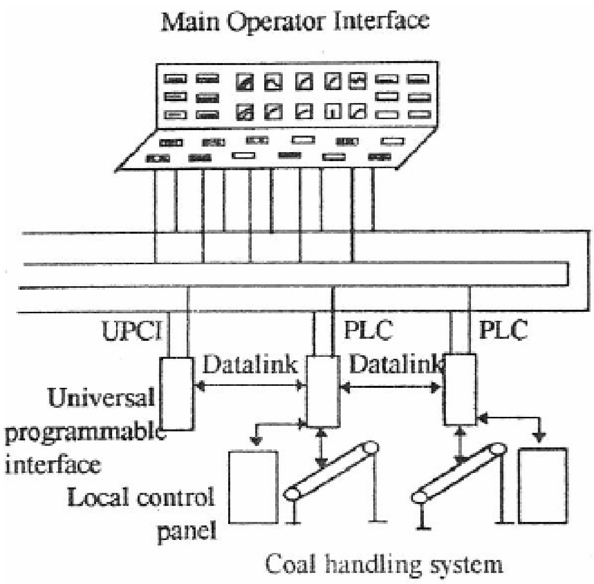


Fig. 3. PLC Control and DCS VDU/Local Control Panel Operator Interface

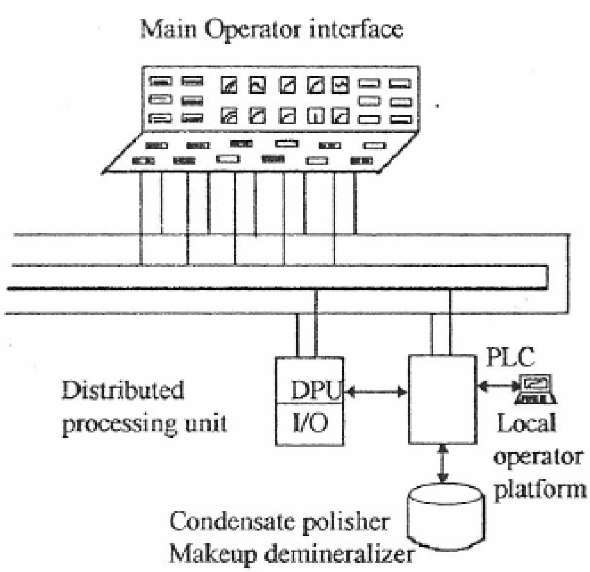


Fig. 4 - PLC Control and Local Operator Interface

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