SUPERVISORY DISTRIBUTED COMPUTER CONTROL SYSTEMS

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Summary

Supervisory Distributed Computer Control Systems help the operator to run the process by putting control and monitoring functionality at his or her disposal. These systems support the Human Machine Interface, Message Handling, Archiving, Hardware Diagnostics and they execute control functions automatically. With respect to these requirements, the functionality of supervisory distributed control systems has remained nearly unchanged in the last two decades. In contrast, the structure of the underlying communication and computing systems changed dramatically, driven by the revolution in Internet and PC technology. This section illustrates the principle functional requirements and presents a brief introduction to modern system configuration concepts.

1. Introduction

The task of the supervisory distributed computer control systems is to assist the staff in the control of its plants and in the control and monitoring of its production processes. Such supervisory control systems are important parts of information system infrastructure of a plant.

As shown in Figure 1, they are responsible for all operative functions concerning the supervision and control of the real physical process within the plant.

Plant management systems help the staff in managing the plant. There are various kind of plant management systems for various purposes.

Well-known examples are:

- Labor information management systems
- Recipe management systems
- Production planning and scheduling systems
- Enterprise management information systems
- Engineering systems
- Maintenance systems

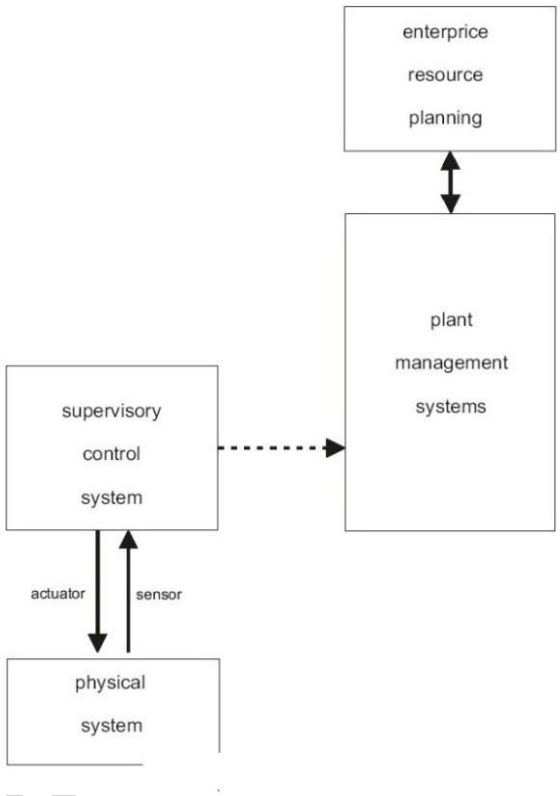

Figure 1. Information Systems - Infrastructure

Enterprise Resource Planning Systems support management of commercial and logistic functions.

In this chapter the structure and the function of supervisory control systems is discussed. The structure is discussed on the basis of reference models corresponding to the fundamental structures of current systems.

The supervisory control systems must perform a number of distinct functions.

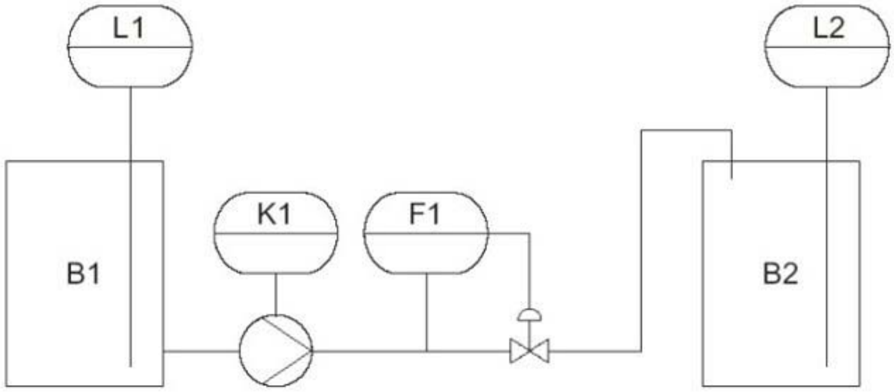

Figure 2. Example metering system

Figure 2, for example, shows a metering device. The required functions can be classified as follows:

- Control the process Automation functions that permits the self-contained control of plant units and process steps. Example:
  - If action „metering on“, then meter from B1 to B2 x liters at *q* L/s.
- Enhance the safety and reliability of the process
  Functions prior in time, independent of control function specifications, that intervene in the process in order to enhance its safety and reliability. Because of high required availabilities and special performance provisions, these functions are often implemented in a separate „protective level“. Example:
  If L2 > L2max, pump K1 is disabled.
- Provide information display
  Display functions that report plant and process status to the operator in a concentrated and easily understood form. Example:
  - Display level L1.
- Generate messages
  Message and alarm functions that explicitly notify the operator of certain events and provide information to the central message and alarm processing system. Example:
  - If L2 exceeds L2max, transmit a message..
  (Class: „Alarm“, text: L2max alarm“)
- Enable archiving of
  Archiving functions to store records of events and status logs. Examples:
  - Archive all reports.
  - Archive level L1 every 10 s.
- Generate and interpret reports
  Recording and evaluating (interpreting) functions that retrieve, evaluate, and print our archival and current data when a certain condition or command occurs. Example:
  - Log the last metering operation performed (starting time, ending time, quantity, events).

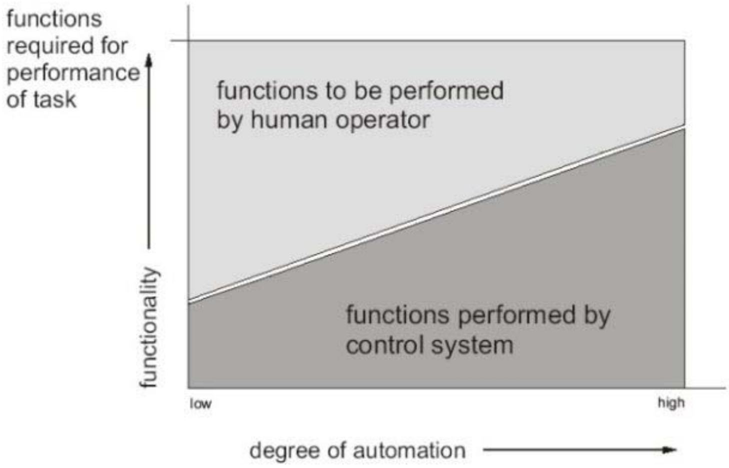

Figure 3. Automation Level

The functions that a specific supervisory control system must perform can be listed in a list of requirements. In principle, a project specification consists of a list of such required individual functions. Some of these functions, as shown in Figure 3, are carried out by the plant operator, the rest are carried out by the process control system. The term “automatic“ refers to a function that is performed by the process control system without external action. The degree of automation is the fraction of all functions that can be represented by automatic functions.

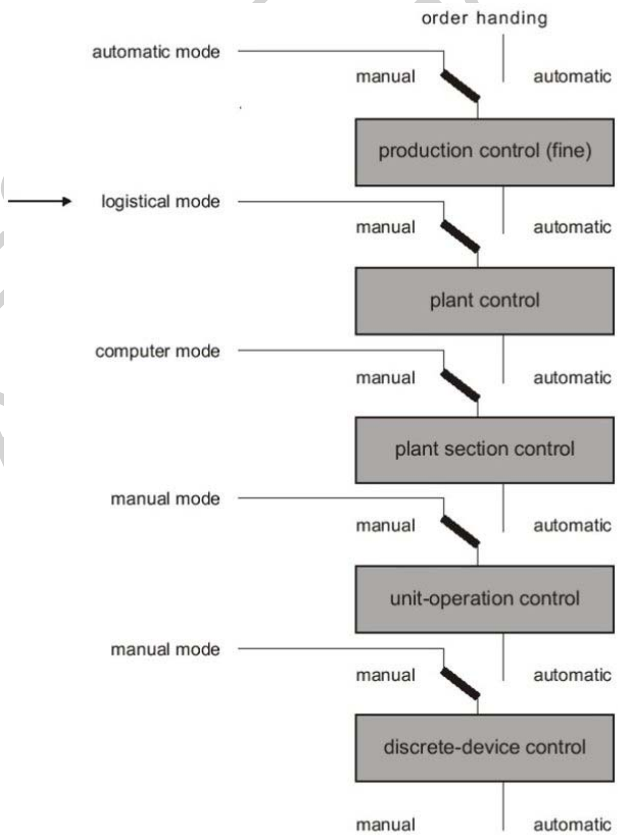

Figure 4. Auto/manual selection

Nevertheless, the overall scope of the control task must be considered regardless of the degree of automation. Each function that does not take place automatically must be manually performed by the plant operator. By changing the operating mode, the instantaneous degree of automation can be reduced (see Figure 4).

When examining the properties of a supervisory control system, a distinction must be made between the external functional viewpoint and the internal structural viewpoint. The external functional view regards the finally configured process instrumentation and control system as a “black box“ having certain functional qualities. The internal structural viewpoint regards how the system is structured and how the individual functions are implemented.

From the process control standpoint, the internal structure of the supervisory control system is often of secondary interest. The required automation functions, safety and reliability functions, archiving functions, operator and monitoring interfaces, and so forth can be implemented using various system concepts. The differences, however, manifest themselves in important supplemental properties.

The plant operator, for example, might see differences in system reaction times, the way in which data surges are controlled, the failure characteristics of components, or the central coordination of workstations. Important from the plant management viewpoint, then, are additional properties that cannot be implemented simply as individual functions but result from the structure of the process instrumentation and supervisory control system design as a whole. Such additional important properties include:

- Transparency of system structure
- Ease of operation
- Structure with low defect rate
- Capability of modular expansion
- High availability of individual functions

These can be realized only if the properties are incorporated in the control system design, i.e., in the internal structure, right from the very beginning.

2. System and Component Structure

2.1. The classical decentralized process control system

Figure 5 shows the structure of a classical decentralized process control system.

All stations are coupled via the system bus. Any station that has an I/O interface to the field is regarded as a process station, while any station that has no I/O interface to the field is considered to be a central station.

Process stations are generally organized with respect to the structure of the plant. All sensors and actuators of a plant section are coupled exactly to one process station. A process station controls and monitors the plant sections assigned to it. It gets new setpoints via the system bus and places all its process information at the other stations disposal, but by carrying out its control task, it is autonomous and independent of the communication on the system bus. With respect to this behavior, process stations are also named automation stations (or automation controller, automation systems, etc.).

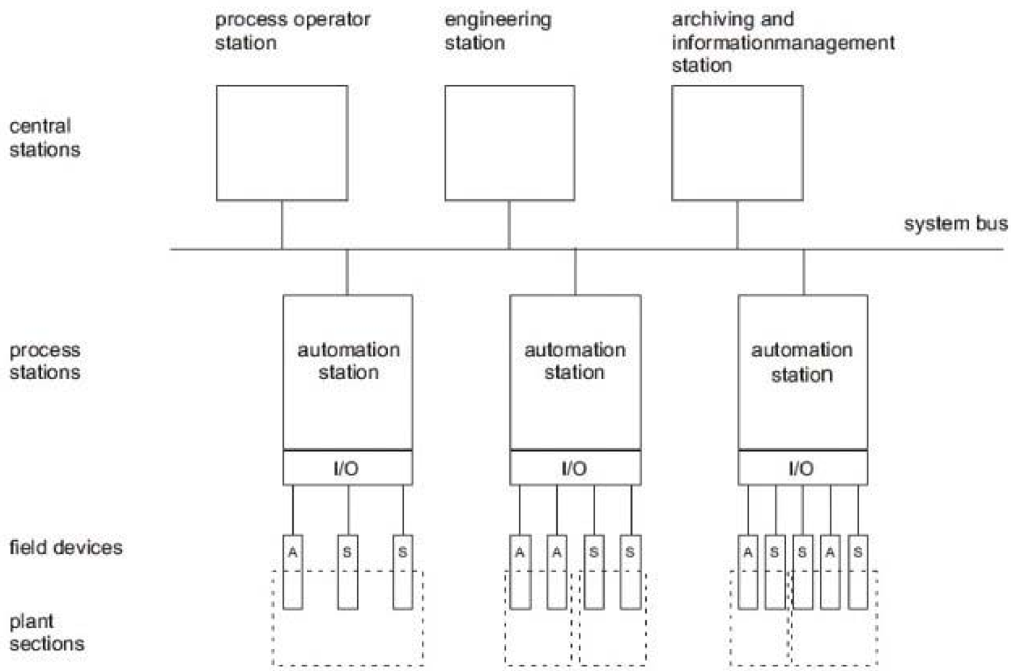

Figure 5. Structure of a classical decentralized process control system

Central stations embody functions that are not directly a part of process-level control and monitoring. Examples of such functions are central operator functions, archiving functions, evaluation and interpretation functions, logging functions, production control functions, recipe control functions, and also engineering functions and diagnostic functions (6). The division of labor can be modified from case to case.

The control stations are typically organized with respect to the type of required functionality and not to the structure of the plant. In many classical systems this is not a question of design but a must. The manufacturers offer different station types, each able to realize only one specific function. Figure 5 shows a usual spectrum.

The system bus is the nerve center of the supervisory control system. The following services, among others, are performed via the system bus:

- Delivery of requested data (from any station to any station)
- Transmission of operator commands, acknowledgements, and instructions from central process and production control functions
- Provision of required data to the central archive
- Delivery of messages and alarms to the message receiving systems
- Object manipulation and object information to assist central engineering
- Loading of actions (production specifications, execution specifications)
- Internal update functions when individual components go out and are

restarted

- Temporal synchronization

To be acceptable for process control purposes, a bus must have the following technical qualities:

- High availability
- Insensitivity to electrical and electromagnetic interference
- Deterministic behavior, even when under load
- Open architecture (compliance with international and de facto standards)
- Hardware and software capable of adding or deleting subscribers while bus is in operation

All system buses that are available today, while they do use standards for certain levels, still represent manufacturer-specific solutions on the whole.

If the transfer requirements imposed on a system bus in a classical process control system for controlling the process are considered, it can be seen that a gross transfer rate of 1 Mbit/s is sufficient for such tasks, even in larger networks. The net transfer rate strongly depends on a choice of individual transmission services and the network data distribution model.

Bottlenecks can occur, for example, when archives are updating one another, when static image information is being transmitted over the bus, or if an unsuitable data model has been chosen. A typical example of a transfer-intensive data model is the centralized mirroring of all local component status information at remote component locations.

In the assessment of a bus system, therefore, the gross transfer rate is less important than a well-thought model of data management and data sharing on the network.

The sensors and actuators are capsulated single units. They work internally according to an analogous or digital scheme. Analogous devices are typically parameterized and calibrated by opening the device and using a screw driver. Digital devices usually offer a local HMI (Human Machine Interface), which allows the main settings to be set without opening the device. In the classical structure, the sensors are typically coupled to the system by signal lines.

To connect these lines to the process stations, special I/O-modules are needed. For example, input models are needed in order to feed and read two-wire transducers; to process the signals from NAMUR initiators, strain gauges, and mechanical contacts; to acquire and linearize thermocouple and Pt 100 signals; to handle multi-range frequency inputs; and to process 0(4) – 20 mA, 0-10V, 0-24V, BCD, and other input signals from units. The corresponding output modules provide the following functions: output of current/voltage signals, possibly into standard loads (up to 24 V); power outputs for solenoid-actuated valves; floating outputs; pulsed outputs for integrating positioning drives; and so forth.

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Biographical Sketch

Prof. Dr.-Ing. Ulrich Epple is head of the chair of process control engineering (Prozessleittechnik) at the RWTH Aachen. His special research activities are the modeling of information-systems in the process industry using formal methods and the development of open infrastructure concepts.