AN INTEGRATED CONTROL SYSTEM FOR A CHEMICAL PLANT

Prepared by the USSR Council on Integrated Systems

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May 1975 WP-75-56

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This paper is intended to submit general ideas concerning an integrated automatic control system for an industrial plant with continuous technological processes, essentially in the chemical industry.

This paper also attempts to present important stages of automation evolution in chemistry and general principles of integrated systems. Taking as an example a large-scale structure of the integrated automatic control system (IACS) for a large chemical complex, the methodology of its development is presented.

This paper has a descriptive character and the terminology used here may be considered debatable.

Introduction

At present automatic control in the chemical industry enters a new phase of integrated systems development.

Considering the evolution of automatic control in the Soviet chemical industry during the last twenty-five to thirty years, one can outline four main stages of the evolution of automatic control systems.

The first stage, local automation, was predominate until the fifties. The chemical industry at this time was equipped with various instrumentation and control systems, essentially for separate technological parameters. Advances in the theory of automatic feedback control served as the scientific base of this stage, and progress in the field of electronic and pneumatic instruments formed a technical base.

The second stage is the development of technological unit control systems. The first experience in the introduction of computers occurred at this stage. At this time the first control systems of this type were developed, sometimes using small specialized computers or devices as well as relay or electronic loggers and scanners. General purpose computers of the first and second generations were used to solve some control problems connected with the organizational and economic activity of the plant.

The third stage, complex automation, is characterized by the extensive application of computers both for the control of technological processes and the plant as a whole. Computing centres are established; ranges of problems broadened and technological unit control problems are interconnected. Systems tend to be integrated and hardware and software of the system are both standardized and unified. By this time, control systems for complex units were developed. At this time control systems were divided into two groups: I) automatic control systems for technological processes (ACSTP) and 2) automated control systems for the plant as a whole (ACSP). It should be noted that the development of these systems, as a rule, were performed separately.

Small or specialized mini-computers (for local automatic process control systems) and middle and large computers of the third generation (for automated control systems of the plant) are used as the technical base for the given stage.

The general number of control problems implemented at this stage is large enough, nevertheless, control systems of this period, as a rule, represent the set of slightly connected or absolutely separate algorithms, programmes and devices. Automatic control systems for technological processes (ACSTP) and the plant (ACSP) differ widely.

At present all prerequisites for going to the fourth stage of automation - integrated control system stage - are created.

Main Definitions and Theses

A control system can be called integrated when it covers all aspects of the activity of the controlled plant and the aim is to achieve optimal or a more rational functioning of the plant as a whole. This system is based on general principles and methodology. A distinctive feature of the integrated control system is an interdependency of the interconnected local (primarily independent) systems into a general whole. Such features of control system integration allow the attainment of a system of new quality and high efficiency.

The Integrated Automated Control System for the plant (IACSP) is designated as the system which realizes both organizational -economic, off-line control of the plant and on-line operational processes control. This system is characterized by I) hierarchically interconnected sets of functions directed to increase the efficiency of the production process, and 2) by the interconnected set of algorithms, which are the same as technical and organizational concepts based on systems analysis methodology.

The problems of interrelations of the subsystems in the integrated automated control system are of a functional, infomational, technical and organizational nature.

The base of the functional integration is a common criterion for the whole system. Obviously, it is not possible to speak about a common constant criterion for an integrated control system. Such indices as profit or profitability may be considered as a single global criterion of the IACSP only in separate particular cases. Nevertheless, it is possible to define a number of such criteria (with definite, although not always with constant priorities) which should be achieved by the IACSP. Criterion of separate subsystems should be formed as a result of the decomposition of common criterion. These should be in conformity with each other.

Integration of the information processing is associated with the development of a common system of information input, monitoring and renovation, with the possibility of data exchange between separate subsystems, and establishing a single data base.

The integration of hardware is particularly significant. The integrated automated control system in most cases includes several computers of different types, which are interconnected into a multicomputer complex by communication channels. Data are transmitted into the system by different ways: automatically from technological transducers, manually from operator consoles, punched cards and tapes.

Data output can have a form of cards or tapes as direct input into control subsystems of the lower level. It is imperative that such a system be extremely flexible and reliable.

The necessity of the integrated approach to software of separate subsystems and the IACSP as a whole, is apparent.

The model aggregation of different hierarchical levels and all the requirements to the system dispatcher programmes for the proceeding of the problems solution, including the rational organization of computer control programmes should be considered by the integration.

An organizational aspect of the integration, which is of extreme importance, is the rational man and machine interface, the distinct division of functions between machine and the people employed in control.

At the design stage the decomposition of the whole system is of great significance. The necessity of such a decomposition lays in the very nature of the integrated system. However, depending on the type of partitioning, decomposition may be performed in a variety of ways. There are different types of decomposition: considering the time scale of the problem, aspects of the system activity,organizational structure and solution complexity levels.

In the chemical industry the IACSP is generally decomposed into two parts: I) an automated subsystem for organizational and economic control (ASOEC) and an automatic on-line control system (ASOLC). This decompisition is defined to a large extent by both the activity aspect of each of these parts and by the time scale of the problems to be solved. A further decomposition according to activity aspects and a functional feature (according to the so-called "strata") makes possible the distinguishing of an automated subsystem, such as: finance control, sales control, main and auxiliary production control, labour resources control, etc.

As a result of the decomposition of the organizational structure (echelons), the production units control systems can be outlined (shops, production plant as a whole).

Such an approach leads to the creation of a multilevel hierarchical control system, each level of which has several subsystems, the higher level performs the role of a co-ordinator relative to the lower levels.

The decomposition, based on the decision complexity levels, leads to the determination of separate control layers, such as monitoring, data logging, production condition, identification, optimization, etc.

Each of the systems is compiled by the intersections of several decomposition directions. Undoubtedly, such a method of the decomposition upon subsystems is not the only one possible. It should be noted, however, that any decomposition should not destroy the community of the integrated system (dialectical combinations of independency and community of the system's separate parts).

The problem of a rational succession and a common methodology of the integrated system development is currently under consideration, especially at industrial plants of the IACSP. It is natural that in the development of such a large system, as in the integrated automated control system for a large chemical plant, large teams of different organizations are involved, which differ in the character of their activity. To make their task more efficient, the methodological unity of such a complex task is a very important problem. In our opinion, an evolutionary way of integrated systems development, by the evolution of the degree of the integrity of separate aspects of the system, is the most viable method. Dividing the problem of the IACSP design in separate stages helps to revise the design of the subsystems considering the final objectives.

A methodological principle of a deductive (from a common control task to separate subsystems' tasks) as well as the inductive approach (by means of analysis and formalization of the existing functions and control methods) to the construction of integrated control systems is extremely important. A reasonable application of this principle provides for, in particular, a regular settlement of the contradictions permanently existing between the separate development and adjustment of the subsystems and their connections. In this case an application of the iterative development procedure is the most useful one. Each step of the development of the integrated system for the plant control, either the development of a technical task, a technical project, or a hardware project, etc., is formed of two phases: a phase of a study of decisions assigned for a separate subsystem and a phase of intersystem interfaces.

In conclusion, it should be pointed out that decisions adopted in the development of the integrated system should be unified as much as possible. Primarily, it concerns the types of the hardware of data acquisition, transmission, processing and display with the necessary unified interfaces. It also concerns algorithms and programmes, the unification of which simplifies the compiling of working programmes for the IACSP.

An Example of the Development of the IACSP at a Large Chemical Plant

As an example of the realization of the main concepts previously mentioned, a short description of one of the chemical plants which is in operation with an integrated control system is presented.

The plant is a large industrial enterprise producing more than fifty types of different chemical products, such as: ammonia, nitric acid, various mineral fertilizers, organic synthesis and chloric products. At the plant there are about forty separate departments with more than one thousand units of basic technological equipment. A continuous process of a primary raw material processing into the finished product is typical for most of the departments.

The plant control is achieved by means of a number of functional divisions co-ordinating all the production and economic activity within the plant and also performing numerous communications with raw material suppliers and customers.

As it was stated above, the main parts of the IACSP are the ASOEC and ASOLC - used instead of terms: automated system for plant control (ACSP) and automatic systems for technological process control (ACSTP).

The main task of the organizational and economic activity control is the organization of production, provision of necessary resources (equipment, raw materials, people, finances) for the plant operation in the condition of permanently changing production situations. This task is achieved by the separate functional control subsystems which form the ASOEC.

All functional subsystems are divided into two groups: the first group includes subsystems which do not have direct connections with the production (control of finances, labour resources, supply, marketing), the second group includes subsystems for the production control and partly for the control of auxiliary departments. The type of problems to be solved to a large extent, defines the type of models used in the subsystems.

For the first group of problems it proved to be possible to use standard models, and even programmes; and for the second group, it was necessary to develop new models and software to satisfy the specific requirements of the production processes. Sometimes the second group of subsystems, especially important in the functional respect, is called the kernel of the automated control system.

The main task of the operational on-line control is to provide for an optimal functioning of the production processes. This task is solved by the ASOLC which combines in a hierarchical system all the separate automated control systems for interrelated complexes of departments and production units. The integrated system is characterized by having a large number of information inputs and control outputs.

So, the integrated system at its higher level consists of a group of functional subsystems for organizational and economic control and multilevel hierarchical on-line control systems (ASOLC). A harmonic interconnection of these subsystems in functional, informational, technical and organizational aspects in the main task of integrated control system design.

To achieve this task an iterative method of designing the system was adopted methodologically. The first iteration is a preparation of a technical project of the whole system in which all subsystems of organizational and economic control are approximately described, then the co-ordination and correction of separate subsystems are performed; the second iteration is a technical project of subsystems, the third is a project of the given subsystems hardware. By this method, all subsystems finally are designed separately and each subsystem is able to function normally, if another subsystem fails.

To provide interconnections between separate subsystems, the so-called common part of the ASOEC was designed. This part of the ASOEC project includes information flows between subsystems, a general data bank of the plant, a time sharing system and also a system for the subsystem information data banks modification.

The part of the automated system related to the on-line control has three levels of hierarchy: control of the whole plant, control of large production departments and control of separate production regions.

Taking into consideration the requirements of the unification mentioned above, typical technical solutions, and in some cases even standard control systems were used, according to the previously obtained experiences.