UDC 66.012-52

DISTRIBUTED CONTROL SYSTEM IN CHEMICAL PROCESS

Toshiaki Suganuma

1 FOREWORD

Many types, small lot production is given as a special feature of the batch process in the chemical industry. The operation management and control system for producing products of infinitely divers names at the end of the process by combining many kinds of raw materials is a complex production system.

The distributed control system has sophisticated control and computation functions and data processing functions, and substantial results in improved batch process quality and productivity can be expected.

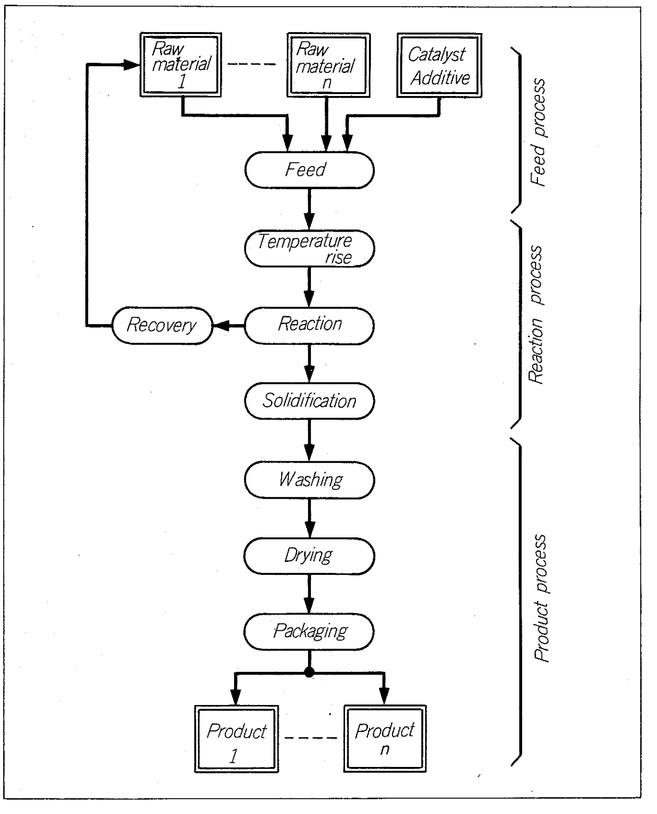
The system design policy and application method when using a distributed control system at a batch process are described here.

2 OUTLINE OF BATCH PROCESS

Generally, the field known as synthetic resin, paints, medicines, and other fine chemicals has many batch processes. In this field, name changes and quality changes are frequently made to meet changes in market demands, and because of processes with nonlinear, lag time, sophisticated control and flexibility matched to these are demanded of the control system.

The processes of a typical batch process are shown in *Fig. 1*.

Fig. 1 Processes of typical batch process



At the feed process, raw materials, catalysts, and additives are sent to the polymerization tank in accordance with the specified feed amount and feed sequence based on the production quality and production name.

At the reaction process, which is the most important part of a batch process, the temperature is raised according to the name-inherent temperature program pattern and reaction is performed. Later, there are washing, drying, and packaging processes.

The general features of a batch process are shown below.

(1) The number of many types, small lot production processes is large.
(2) Operation at starting, stopping, and other irregular times is complex.
(3) Reaction at the polymerization tank must be accompanied by high precision controlability.
(4) The operating conditions and control pattern are changed frequently.
(5) The itterrelationship between temperature, pressure, and other analog quantities and sequence operation of valves, pumps, agitaters, etc. is complex.
(6) From the standpoint of operation management, ample consideration must be given to erroneous operation. Moreover, since there are many different kinds of products, the feed amount, reaction temperature, elapsed time, and other operations at each process must be closely controlled.

[3] DISTRIBUTED CONTROL SYSTEM INTRODUCTION DESIGN POLICY

Although called simply batch process, there are many kinds of processes. Even polyermization tanks, distilling towers, and other comparatively numerous processes have diverse reaction conditions, evaporation conditions, equipment sizes, etc. There are many cases where the control system of other processes cannot be used directly.

Therefore, when introducing a distributed control system, ample system design evaluation between the user and manufacturer is necessary for the system to amply display its functions.

The points to be considered when introducing a distributed control system are described below.

3.1 Control system

The flow sheet of a classic batch process is shown in *Fig. 2*. Batch process control is mainly raw materials feed control, polymerization tank control, and sequence control which performs these in an established order.

3.1.1 Raw material feed control

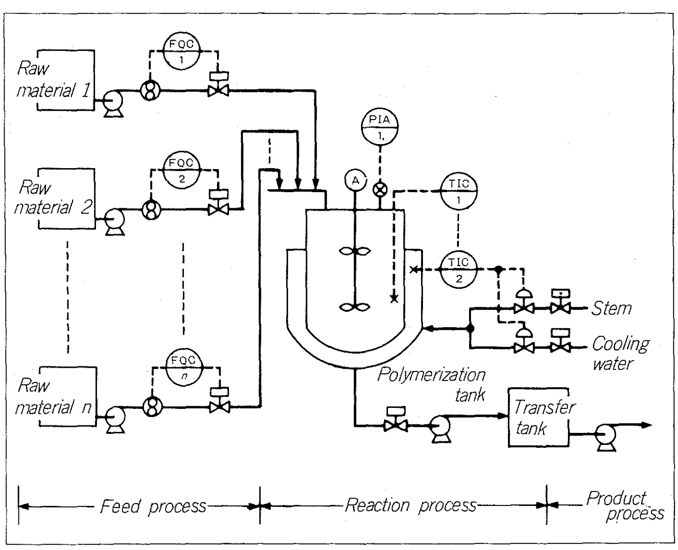
Sequential and fixed amount feeding of diverse raw materials is performed in accordance with the established feed amount and feeding sequence according to name. When there are multiple polymerization tanks in the same feed line, the raw materials are sent to the polymerization tanks by interlocking them. Besides, consideration for reducing the feed time is also necessary.

The name data is stored in a batch in the name file and the data selected by the operator becomes the set value to the feed quantity control (FQC) system.

3.1.2 Polymerization tank temperature control

In a batch process, it is no exaggeration to say that the quality of the reaction of the polymerization tank governs the quality of the product.

Fig. 2 Batch process flow



Reaction temperature control demands extremely precise controlability. In many cases, the control range is about ±2 - 3° for a reaction temperature of several hundred degrees.

The temperature control block diagram of a polymerization tank is shown in *Fig. 3*.

Concerning the control procedure, since the polymerization reaction is an exothermic reaction, first the jacket temperature must be raised up to the reaction temperature by steam valve by secondary PID. After reaction starts, the steam and cooling water valves are controlled in accordance with the required temperature rise curve by utilizing cascade control by primary PID.

This control point quickly reaches the set value at which there is no overshoot.

The points considered from the standpoint of control are shown below.

(1) Prevention of overshoot

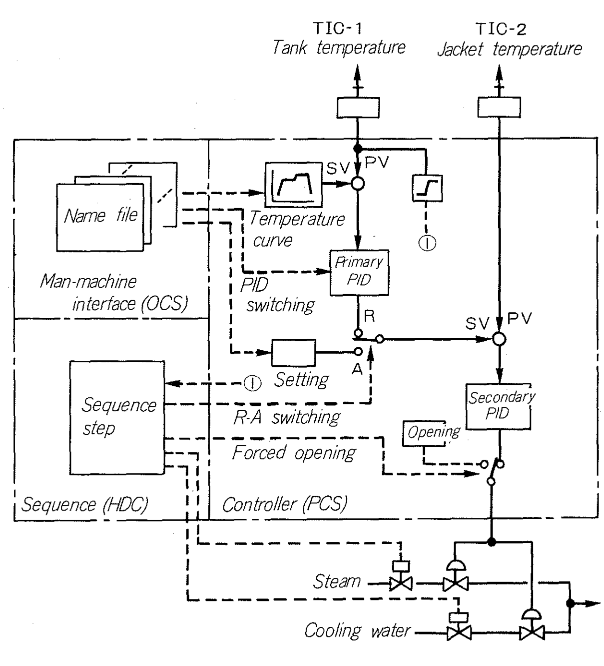
(a) P/PID operation swithcing

At temperature rise, operation is switched to P operation and when normal, operation is switched to PID operation.

(b) Forecasting control

Before cascade control by tank temperature is performed, the residual heat effect in the tank, which

Fig. 3 Polymerization tank temperature control block diagram



Item		Temperature rise	Reaction	Cooling
Control	Primary	—	Program	—
	Secondary	Constant	Cascade	—
Control objective		Jacket temperature	Tank temperature	Tank temperature
Actuator		Steam valve	Cooling water valve Steam valve	Cooling water

is a cause of overshoot, is removed by lowering the jacket temperature for a fixed time.

(2) PID constant switching
The polymerization tank is generally divided into temperature rise, reaction, and cooling processes. Since the process time constant is different for each process, the PID constant is sequentially switched. There are also cases where the constant differs with the name.

(3) Reaction end point detection
In many cases, the end of reaction is controlled by time, but may also be automatically detected by temperature, pressure, or other process value.

3.1.3 Sequence control

In a batch process, sequence control is performed in accordance with the process value, time, and other batch data (plant operating conditions). Because the control side data are used as the conditions, or the conditions (mode switching, forced opening program start, etc.) are given to the controller from the sequence side, this interface must be amply studied. The points which need special consideration are:

(1) Automatic/manual switching range
(2) Semiautomatic process step feed
(3) Sequence hold
(4) Processing of faults
and so forth.

3.2 Man-machine interface

Batch process operation is more complex than a continous process, and there are also many cases where quality is maintained by operator intuition.

With a distributed control system, operation is centered about a CRT. Since a batch process has numerous constants and they are frequently changed, centralized control by CRT is extremely effective.

The functions required by a batch process, besides those of an ordinary CRT operation panel (alarm, group, loop, etc.), are shown below.

3.2.1 Supervisory and chontrol functions

(1) Process operating status display
(2) Process progress status display
(3) Name data display and operation
Feed amount, feed sequence, temperature rise pattern, reaction tank temperature, pressure value, elapsed time of each process

3.2.2 Data processing functions

(1) Name data management
(2) Batch report generation (feed amount, temperature, pressure, time)
(3) Process end, congestion printing
(4) Process value alarm printing

3.2.3 Maintenance functions

Because of the nature of a batch process, process modification, restructuring, and name addition are frequently performed. Therefore, even the user must make simple software corrections.

3.3 Study items in system design

A distributed control system has various features, such as solution of the problems of unstable reliability of the conventional centralized control system using a mini-computer and high quality control which cannot be realized with analog instruments. Conversely, if the functions are excessively evaluated, the system will become complex and reliability may also drop. The points which are considered from the standpoint of system design when used at a batch process are described below.

3.3.l System functions distribution

With a batch process, division of the batch system and processes is clear. If controllers are installed to correspond to this division, the generation of trouble is minimized. Moreover, regarding the division of controllers and man-machine interface, concerning the data needed in control, the amount of name data, scale data, and other data is large at the control side and the data which does not have a direct affect on operation should be at the man-machine interface side.

Besides, installing the temperature rise switch and emergency stop switch, which are the main operating points, separately from the CRT system as special switches improves the reliability and operability of the system.

3.3.2 Redundancy

A redundant system should be judged from the standpoints of process safety, operator load, cost, and so forth. However, regarding the polymerization tank, since there are extremely dangerous states, such as reaction runaway, etc., consideration must be given to redundancy, installation of a back up power supply, etc. at the minimum.

3.3.3 Backup

To safely stop the process even when the system shuts down, a backup manual switch, graphic panel, recorder, etc. are considered.

The functional composition of the Fuji Electric distributed control system (MICREX) is shown in *Table 1.*

Table 1 MICREX functional composition

	Device	Function
Operation, supervision and control	• Operator station OCS-1100, 1000, 100 • Man-machine controller PMS-100, 200	• Name data control • Process control • Batch report generation • Graphic display • Daily report, alarm messages
Control	• Process station PCS-100 • Sequencer HDC-100 • One loop controller PMK, PMA • Unit process controller UTC	• Raw material feed control • Polymerization tank program temperature control • Control constants automatic modification • Sequence control
Others	• Backup actuator recorder • Graphic panel • Manual switch	• Operation support • Backup

Fig. 4 System composition (multi loop)

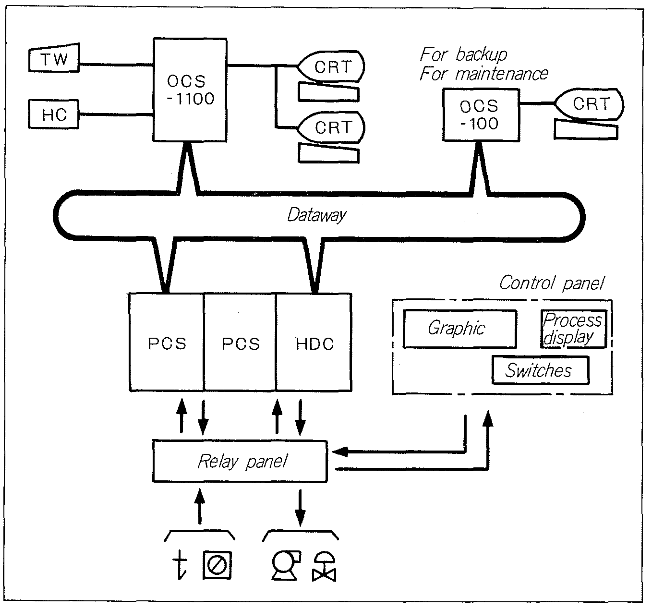
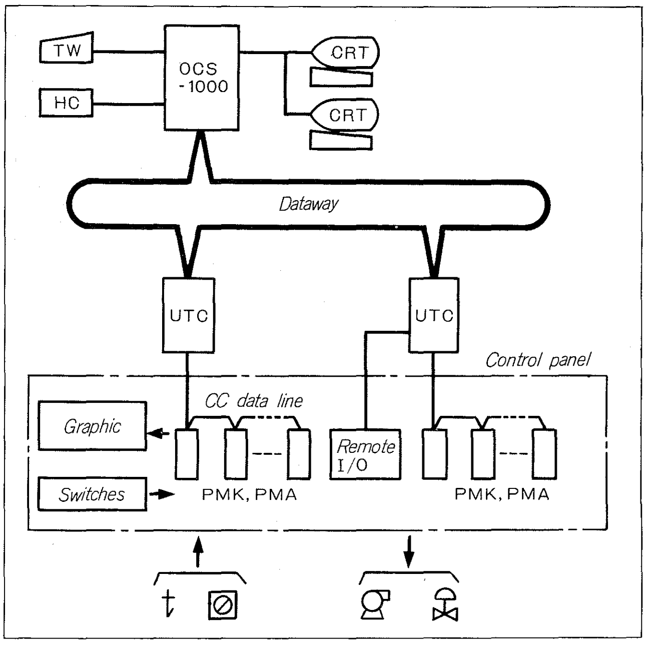


Fig. 5 System composition (single loop)



The MICREX system allows the easy realization of composite control system combining feedback control, sequence control, and data collection. Connection to the same dataway as the HDC series, which permits sophisticated sequence control, production control computer system, etc. is also featured, and it is a system matched to the needs of batch processes.

4 DISTRIBUTED CONTROL SYSTEM APPLICATION EXAMPLES

4.1 Multi loop type

The system composition is shown in *Fig. 4*.

Regarding the controller (MICREX-PCS), control of polymerization tank area and other important parts has a duplexed configuration. A dedicated sequence controller (MICREX-HDC) is organically connected to the PCS by a dataway. The operation station (MICREX-OCS1100) is for operation control, and displays and prints batch reports, etc. A simple type operator station (MICREX-OCS100) is installed for backup.

4.2 Single loop type

The system composition is shown in *Fig. 5*.

This is an example using a single loop controller (compact controller Model PMK, PMA), and is for medium and small scale use.

The merits of this system are that back up actuators are unnecessary, maintenance in one loop units is simple, etc.

At the unit process controller (UTC), controllers (PMK, PMA) connected to the CC data line and remote I/O are connected and PMK and PMA totalized control, sequence control, and processing of transmission with other systems (OCS, etc.) are performed.

5 CONCLUSION

In the past, automation of batch processes was comparatively slow because of the complexity of the operation and control system. However, it will be increasingly introduced in the future by the advance of the distributed control system. The authors will be happy if this article aids in system design and serves as reference development of the ideal system in the future.