技術解説

Recent Instrumentation System Safety Instrumentation and Man-Machine Interface

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—Content—

1. Introduction

The industrial processes have become complicated on a large scale because of improvement of productivity, research of efficiency, and shortage of locations to be suited for foundation of factories. Consequently, the instrumentation and control systems for operating these industrial processes have also been highly improved with the development of mass information means. In order to operate these large-sized and complicated industrial processes safely, the man-machine interface for correspondence between man and machines and the instrumentation system regarding process fault processing are playing an important role increasingly. This paper describes recent instrumentation system in the water purifying plant as an example of these industrial processes, and covers both man-machine interface and process fault processing. The annual water supply quantity and diffusion were 2,000,000,000m³ and 25.0% in 1950 in Japan, but they amounted to 12,000,000,000m³ and 86.7% in 1974, respectively. The demands of water will increase incessantly, while it becomes gradually difficult to secure water sources. Accordingly, local self-governing bodies such as municipal cooperation, towns, and villages often construct a large-scale water purifying plant at one place in common, as required, without constructing respective plants independently. It is an absolute requirement for the water purifying plant to avoid stopping water supply to fullfil its social responsibility from the viewpoints of its public utility enterprise, and also it has gradually become difficult to secure skilled operators enough to cover such water purifying plants that are additionally provided in various districts. Thus, the importance of the man-machine interface for assuring safety operation of the water purifying plant irrespective of unskillfulness of operators as well as the instrumentation system regarding process fault processing, or, safety instrumentation, is more and more increasing as the water purifying plants are on a large scale.

2. Safety instrumentation

The major purpose of the instrumentation system has conventionally been to secure the operation control of the plant, and the process fault processing was entrusted with the operators' judgement and remedial measures, except for automatic processing using a simple interlock system in these stages. Originating from a series of accidents which happened in Japanese chemical industry in 1973, such an instrumentation system that introduces a fault preventive concept into conventional instrumentation system exclusive for operation control, was advocated based on the reflection that conventional instrumentation system for operation control only is not enough to assure safety operation of a large-scale process plant. This is called safety instrumentation. In case of the instrumentation in the water purifying plant, the concept of this safety instrument-

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ation has been adopted since nineteen-sixties (1960s) on such a background that even an unskilled operator can operate the plant safely. It is necessary for realizing safety instrumentation to balance the following four items at a high level.

1) High reliability of equipment proper
2) Complete provision of instrumentation units useful for safety instrumentation, such as explosion-proof structure, arrester, etc.
3) Establishment of back-up system using decentralized control system or duplex system and systematic safety instrumentation by complete man-machine interface system
4) Complete maintenance system

This paper deals with the systematization of safety instrumentation in 3 above.

3. Systematization of safety instrumentation

There are two concepts in solving the systematization of safety instrumentation. One is a back-up concept in instrumentation system faults, and this concept lies in the scope of automatic back-up system. The other concept concerns the scope of fault processing to be entrusted with the operator and fault information system to the operator. However, the safety instrumentation is practically systematized while these two concepts are supplemented with each other. In other words, it is systematized by defining the scope of the functional roles of man and machines. Man is superior to machines in overall judging capacity and high-grade learning capacity. However, these advantages differ according to individuals, and also they are not always kept constant according to environments and physiological causes. These factors are not negligible. On the other hand, machines execute correctly what they have learned once, right or wrong, unless they are in trouble.

3.1 Concept on back-up system when instrumentation system is in trouble

When the plant scale is not so large and its fault processing operation procedure is not so complicated, its instrumentation is composed generally of analog controllers only. It may be considered that the backup system of the instrumentation system may be preferably remote-controlled or manually operated locally, in principle. When the plant is on a large scale, the computer system is introduced for the purpose of improving both control level and equipment efficiency.

The water purifying plant is predictive-controlled based on demand forecast and countermeasures for idle time. However, its control algorithm requires an optimum control for stable utilization of facilities with minimized operation costs. For backing up the instrumentation control system, the computer is designed to be a duplex system and also the decentralized control system using rapidly developed microcomputer as an intelligent terminal has recently been watched with keen interest. The conventional DDC control back-up system using a computer features the back-up means by the duplex system and remote/manual operation at the center and local sites.

In recent years, however, the micro computers are decentralized in the unit of each facility as an intelligent terminal and a mini-computer is installed at the center. These micro-computers and central mini-computer are connected to each other by the information transfer units using data way. In this case, the central mini-computer executes control arithmetic operation regarding the operation of the entire plant, and also performs the supervisory control of each micro computer mounted in the unit of each facility. Accordingly, the central computer executes general functions for micro-computers, such as setting of control target values, fault diagnosis, monitor of control conditions, monitor of plant conditions, switching of control modes, program loading, start/stop commands, and others. In addiiton, the central computer can back up the micro computers installed as interlligent terminals by suitably disigning the system configuration. Thus, the system reliability can be improved by mutual back-up between the central computer and the decentralized micro-computers.

Fig. 1 indicaters an example.

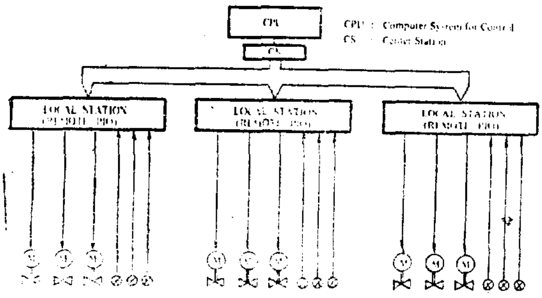

Fig. 1-A. DDC system using Remote-PIO

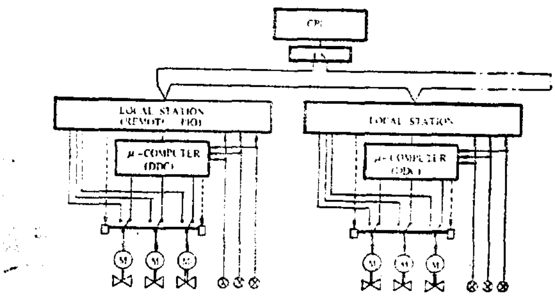

Fig. 1-B. Back-up system for decent alized control system using Remote-PIO

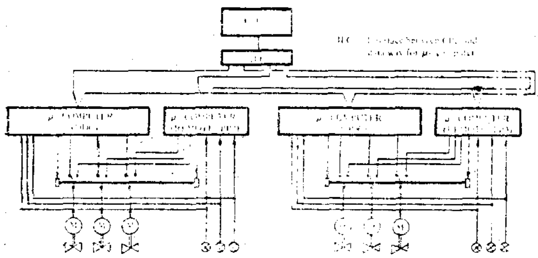

Fig. 1-C. Back-up system for decentralized control system using duplex data way

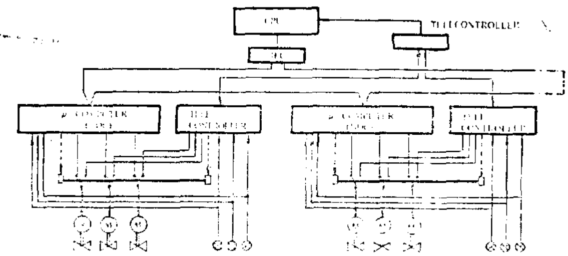

Fig. 1-D. Back-up system for decentralized control system using telecontroller

Fig. 1. Back system for decentralized control system

Fig. 1 Showes an example.

Fig. 1-A showes conventional DDC control system using remote-PIO system. Each local station only transfers the control signals of the central computer to the final controlling elements and also transfers various data from the process side to the central computer.

Fig. 1-B showes the decentralized control with the remote-PIO system local station and micro-computers connected to each other, and the mutual back-up between the central computer and the micro-computers. If the central computer falls down, the micro-computers serve as intelligent terminals, and if a micro-computer falls down, the central computer conducts the DDC control in the same manner as in FIG. 1-A system. The data way is connected in the form of a loop (deplex system) and also the transfer unit in the local station can also be designed as a duplex system, but some non-duplex portions like a power source unit remain in the local station.

Fig. 1-C showes the configuration of a back-up system with a transfer line exclusive for back-up separately installed. In order words, the standard micro-computer data transfer unit is employed for ordinary decentralized control, and also the same series of the transfer line exclusive for back-up system as that for the microcomputer is employed. However, their founctions are identical to those of the remote-PIO system. Accordingly, the relation between the central computer and micro-computers is the same as in Fig. 1-B system.

Fig. 1-D showes ordinary decentralized control system using a simple telemeter controller as a back-up. Since the decentralized control is such a system that has been considered as the back-up of the central computer system originally, the ordinary decentralized control back-up does not adopt the system given in Fig. 1, but employs the manual operation at site, in principle. However, the concept on the back-up of the instrumentation system differs to a large extent according to the objective facilities and concept of users. When it is desired to design the lower cost back-up system the same function as system shown in Fig. 1-C, or improve functions by connecting the

existing remore-PIO system and micro computers to each other, the system given in Fig. 1-B is recommended. For eliminating downtime of the instrumentation system, Fig. 1-C system if preferably recommended. However, if back-up is required for a limited case only, Fig. 1-D system is better than the others. The utilization of micro computers permits reducing the instrumentation work costs by reducing the signal lines to be entered to the central control room while decentralizing the system danger.

Also, it permits extending the water puirfying plant according to the annual plan in most cases. Thus, the system extension can be planned. As described above, various duplex system have been introduced into the instrumentation system easily by technically improving the duplex system as a means of improving system reliability. Thus, the operator can be released from being anxious about blind operation caused by system down.

3.2 Process fault processing

It is very difficult to judge a process fault and a final controlling element fault from the instrumentation system side. However, it is necessary for the instrumentation system to check data closely first and locate the cause of such a fault as quickly as possible. For examining data, the following methods have conventionally been done.

1. Limit value alarm
2. Scale-over alarm
3. Changing ratio alarm
4. Deviation width alarm

It may be considered that the following items must be added for keeping track of process faults from the viewpoints of safety instrumentation.

5. Examinations of input signals judged from operating balance of process

Examinations to see if the relation among the pressure before and after control valve, valve opening, and signals of flow meter mounted on the pipeline is correct or not, for example.

6. Examinations of accumulated value during a certain time and the present value.

Examinations of relation among inflow, outflow, and level of tank, for example

7. Examinations of estimated value after a certain time and the present value

It is, of course, not always necessary to apply examinations in 1-7 to all input signals, but these items should selectively apply to the input signals according to properties of these signals. When the instrumentation system was judge to be in a process trouble, an alarm display informs the operator of such a fault, and then, the control system takes the following measures selectively, as required.

1. Control remains continued as before.
2. Control remains continued as before after switching the faulty unit to its auxiliary one.
3. Final controlling elements are kept unchanged under the present condition by stopping the present control only.
4. The present control is stopped, and the emergency control unit is operated.
5. The present control is temporily stopped and fault processing unit is operated. Then, the system is automatically reset to the previous control after the system has been restored to normal condition.

Since the automatization of process fault processing is related to the equipment very closely, it is necessary to proceed the system design while making contact with the equipment designers closely.

4. Man-machine interface

Manpower saving control, centralized control, and highlevel control are being accelerated to meet the present circumstances of the large-scale, compliated equipment. The control room plays an important role increasingly in controlling the entire system, and the design of the interface between man and various control units directly affects the propriety of the entire system operation to a large extent. Unlike conventional system design, in which the performance, functions, and economy of units have simply been emphasized, the present system design is strongly requested to be done on the premise that the concepts of human first and human center, such as correspondence between man and units, adaptability between man and environments, are taken into due consideration. Accordingly, it is necessary to lay out the instrumentation system in the order of such a man-machine interface system that is easily operable for the operator and then the control room comfortable for the operator.

4. 1 Man-machine interface

The man-machine interface is composed of the graphic panel, control desk, CRT display, printing typewriter, etc. Since these component units are directly operated by the operator when the system is normally operating and also when it is in trouble, it is necessary that the man-machine interface units feature excellent supervisory function, operation ease, and distinct functional divisions. These component units function as described below.

1) Graphic panel

For the purpose of roughly keeping track of operating conditions and systems of the plant, this graphic panel accommodates the graphic process flow indicating the simulated plant on the panel face, operation indicator lamps, and indicating tubes. The graphic panel comprises the mosaic system, acryl label system, and acryl scribing system. This graphic panel permits checking the operating conditions of the plant immediately, and it is effective for quick remedial action when the plant becomes faulty, in particular.

2) Control desk

The control desk serves as a central unit of the man-machine interface. This supervisory control system has the following functions.

(a) Data display

(b) Fault display (plant,equipment machines, instrumentation units)

(c) Data setting

(d) Remote/manual operation

(e) CRT displays picture selection

(f) Telephone and broadcast

Almost all the supervisory functions are centralized into this control desk in recent years, so that the operator can conduct all operations while taking a seat. The control devices are standardized in the electrical equipment and instrumentation, so that the operator can operate these devices by the same procedure and same senses without any particular feeling of resistance of identifying these electrical and instrumentation devices from each other.

3) CRT display

Unlike the graphic panel and control desk which roughly indicate the operating conditions of the plant, the CRT display indicates information and data in detail. The following description covers an example of using the CRT display in the water purifying plant.

(1) Ordinary status display

The CRT displays the process flow of the plant plus the operating conditions, set values, and present values at corresponding places, so that the operating balance of the entire plant can be seen at a glance.

(2) Trend recording

The CRT displays the operating conditions of a certain unit with time lapse at 24-hour or 12-hour point.

(3) Monitor of micro computer operation

The CRT displays the operating conditions of the micro-computers in such a manner that they can be set and operated in the same procedure as in analog controllers.

(4) Alarm display

If an alarm was sent to indicate a fault produced in the instrumentation system, the CRT displays the location of such a fault in a part of a certain unit by means of self-diagnostic function of the instrumentation system. If a fault was produced on the plant side, the CRT displays the name of location where such a fault occurs, present value, and alarm set value, and also it displays the operating method, fault recovery method, or check points to be followed by the operator, for the purpose of preventing an erroneous operation of the operator. As another alarm display method, the process flow of the plant can be displayed to indicate faulty points by flickering or red lamp indication.

(5) CRT display menu indication

This indicates the kinds of various displayable pictures and selection key No.

4) Logging typewriter or line printer

This is used for preparing the operation daily, abnormal data and related data recording, recording of various operating conditions of the plant, etc. It is also used, in recent years, for automatically printing out the names of the units reaching the specified operating time, operating time, specified operating time, etc. for the purpose of preparing maintenance and check manuals for each unit of the plant.

4. 2 Design of control room.

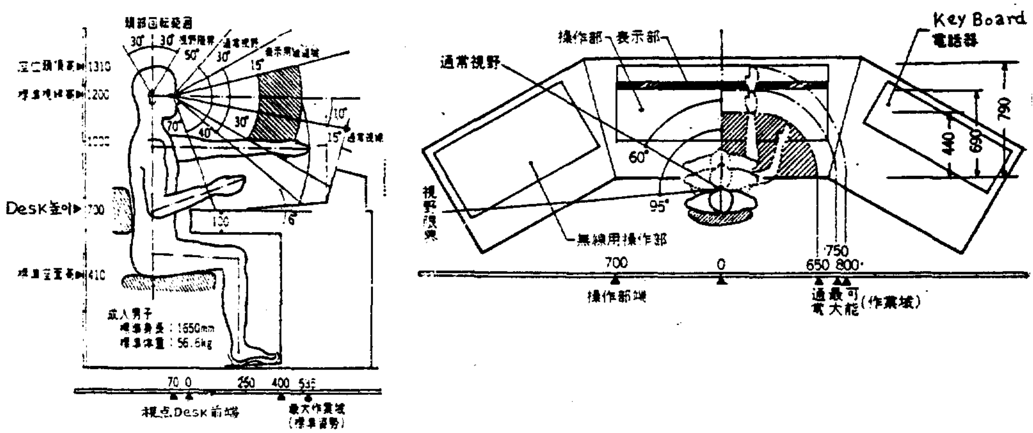

Fig. 2. The standard living body values

The following points should be taken into due considerration for the purpose of applying the system design based on the concept of human first and human center to the control room.

1) Application of living body measuring values

When designing and laying out the graphic panel and control desk, it is necessary to set appropriate values from the living body measuring values and apply these set values to the system design while taking human engineering concept into due considerration.

Fig. 2 indicates the standard living body values employed us.

2) Considerations from the psychological and sentimental viewpoints

The human physiological and psychological points must also be taken into due consideration. When examining the coloring and shapes, it is necessary to examine the sensitive effects and functional effects of senses to man as well as appearances. The panel surface of the control desk is coated with Munsell code N3, for example, for making the indicating lamp color of pushbutton switches distinct. In addition, the monitor face is covered with a transparent dark grey filter over the entire surface for the purpose of helping visual centralization. The appearance is wood grained effectively and closely without adopting hard feeling of metal so as to meet the water supply control room with its human light beauty.

3) Items to be taken into consideration

(1) Window position

(2) Color, position, and brightness of illumination.

(3) Noises and echoes

(4) Air-conditioning and ventilation

(5) Coloring

(6) Others