

# An Instrumentation and Control system for Incineration Plants and a Plant Simulator

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## 1. Introduction

Responding to various needs due to increased waste, environmental requirements and energy problems, incineration plants have advanced to become highly functional, composite and large-scale facilities. To operate these plants safely and efficiently, a distributed control system (DCS) has been aggressively implemented.

The rapid advance in automation of plant control requires operators to quickly respond to non-steady-state operations and plant malfunctions. Therefore,

the task of operator training has recently become an important topic.

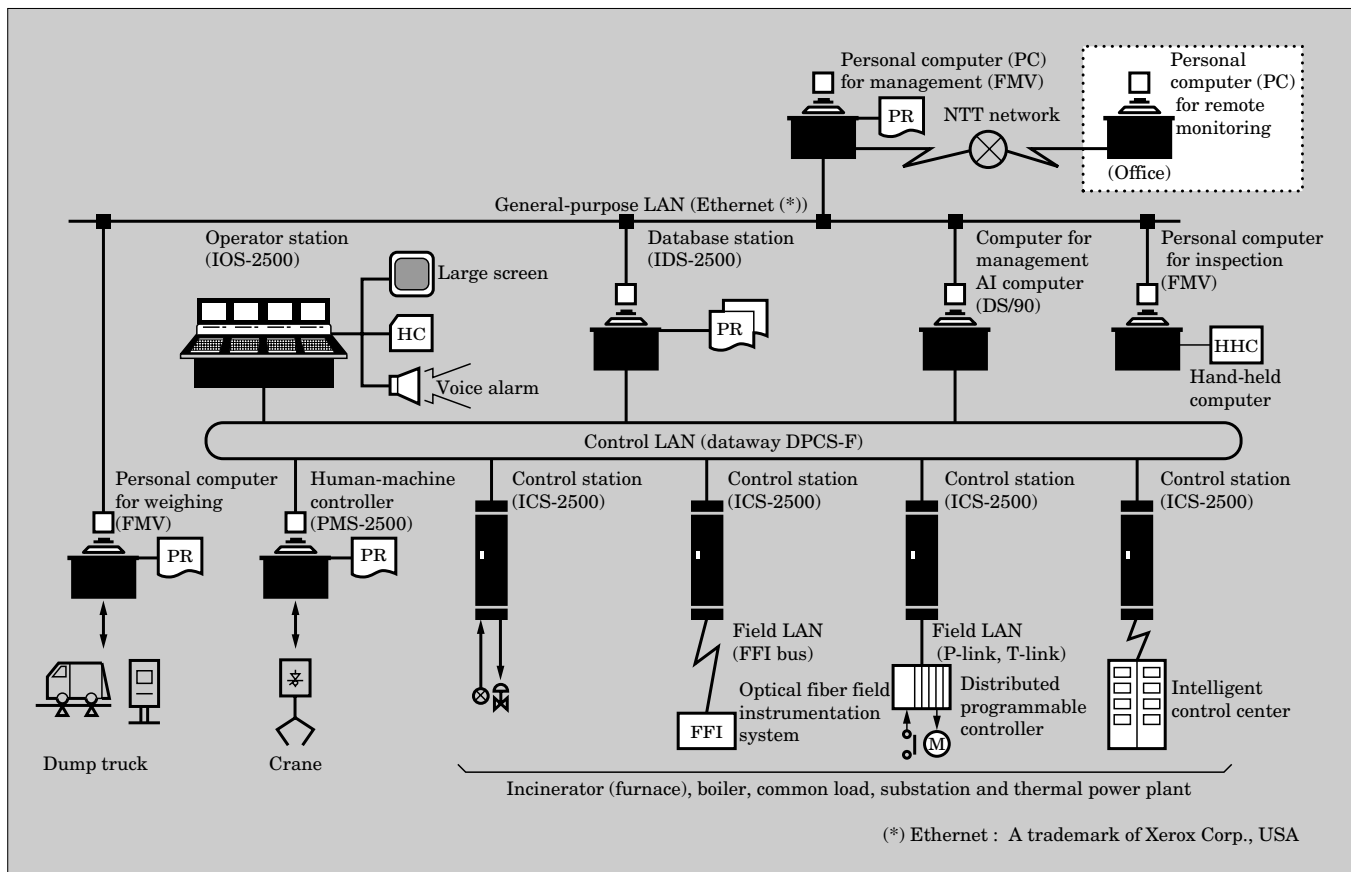
This paper describes the IICS (incinerator instrumentation and control system) and the associated plant simulator that Fuji Electric has recently developed.

## 2. Recent Incinerator Instrumentation and Control System

### 2.1 System configuration

As shown in Fig. 1, the IICS (incinerator instru-

Fig.1 IICS system configuration



mentation and control system) is constructed as an integrated system with the controllers of the MICREX-IX series: the IOS-2500 operator station for human-interface, the IDS-2500 data base station for unified management of the plant data, the ICS-2500 control stations for control of instrumentation, the control LAN (local area network) of the dataway DPCS-F, etc. The PMS-2500, capable of stand-alone monitoring, operation, control, and printing, is applied to monitor and control onsite equipment such as cranes and is also connected to the dataway. In addition, to make an integrated system, the computer for management is connected to the control LAN and general-purpose LAN to control plant data and the personal computer for weighing.

## 2.2 Features of the IICS

The features of the IICS are as follows:

### (1) EIC integration

To safely and efficiently operate and control a large-scale and composite factory, this system is capable of monitoring and controlling information concerning electricity (E), instrumentation (I) and computers (C) on the same CRT display, thus forming an EIC-integrated system.

### (2) Enhancement of the network

The network consists of three hierarchical layers: the general-purpose LAN, the control LAN, and the field LAN, which perform data communication in each layer and between the layers. This network is a high-speed horizontal and vertical data communication system.

Combined with EIC integration, these features are most useful for automating and integrating control throughout the entire factory.

### (3) Enhancement of operation control support system

To reduce the burden of operators, maintenance personnel or factory managers, this system can add the following operation and control support systems.

#### (a) Preventive maintenance, equipment diagnosis and operation support system

Utilizing AI (artificial intelligence) technology, this system forecasts the occurrence of equipment or process malfunctions, signals a warning output, and performs preventive maintenance of the machines and equipment.

Moreover, the system provides operation support guidance to operators for analysis of the tripping process, probable cause assumption, progress forecast, influence forecast, etc.

#### (b) Control system for inventory and equipment ledger

This system uses a general-purpose personal computer to control and readily retrieve spare parts and expendable supplies, the detailed specifications of machines and equipment, their inspection history and their parts replacement history.

#### (c) Inspection data processing system

Using a hand-held terminal to perform onsite inspection before start up of the incinerator and regular periodic site maintenance, this system simplifies inspections and prevents oversight in inspections and mistakes in procedures. The system also connects online with the DCS to link the inspection data.

#### (d) Remote monitoring system

The system can use a remote terminal to monitor various data (alarm, measurement values, trends, and log data) of the incineration plant via a public communication line, determine the operating situation and any malfunctions (RAS information), and then receive remote maintenance service through the maintenance contract with the DCS manufacturer.

## 3. Plant Simulator

### 3.1 Overview of the plant simulator

This plant simulator is a system that simulates the plant operation.

This system provides a means for educating beginner operators, caused by a shortage of skilled engineers, and helps operators acquire skills through an efficient learning plan. This system not only simulates the dynamic performance and behavior of processes, but also improves and maintains knowledge and skill for implementing appropriate measures against accidents or failures that cannot be experienced during normal operation. This system has two kinds of models, the learner model and the plant model. The learner model helps identify the cause of mistakes by a trainee and determines the level of his understanding. The plant model consists of a dynamic performance model, a piping system model, and an equipment model. In addition, the system provides for a learning plan according to the training purpose and the level of understanding of the trainee.

### 3.2 Role of the plant simulator

#### (1) Support for cause analysis when a malfunction occurs

When a malfunction occurs, the plant simulator reproduces historical trend data and provides analysis support.

#### (2) Support for training of plant operation

The plant simulator not only simulates the dynamic performance of the process but also generates a pseudo-malfunction to help the operator determine the behavior of the plant. In this manner, the operator is trained to restore operation after a malfunction.

#### (3) Support for monitoring and operation by the operator

Based on the amount of manipulation by the operator, the plant simulator uses the plant model to simulate possible behavior. Thus, it supports monitor-

ing and operation by the operator.

### 3.3 Hardware and software configuration of the plant simulator

The trainee uses the plant simulator in an environment that provides the feeling of being connected to

Fig.2 Hardware configuration of the plant simulator

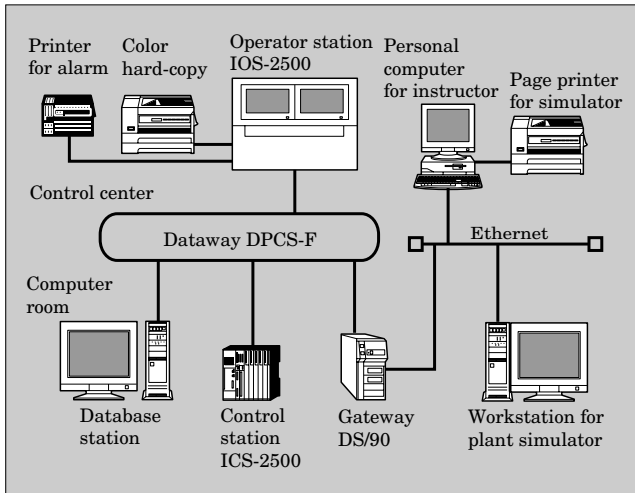
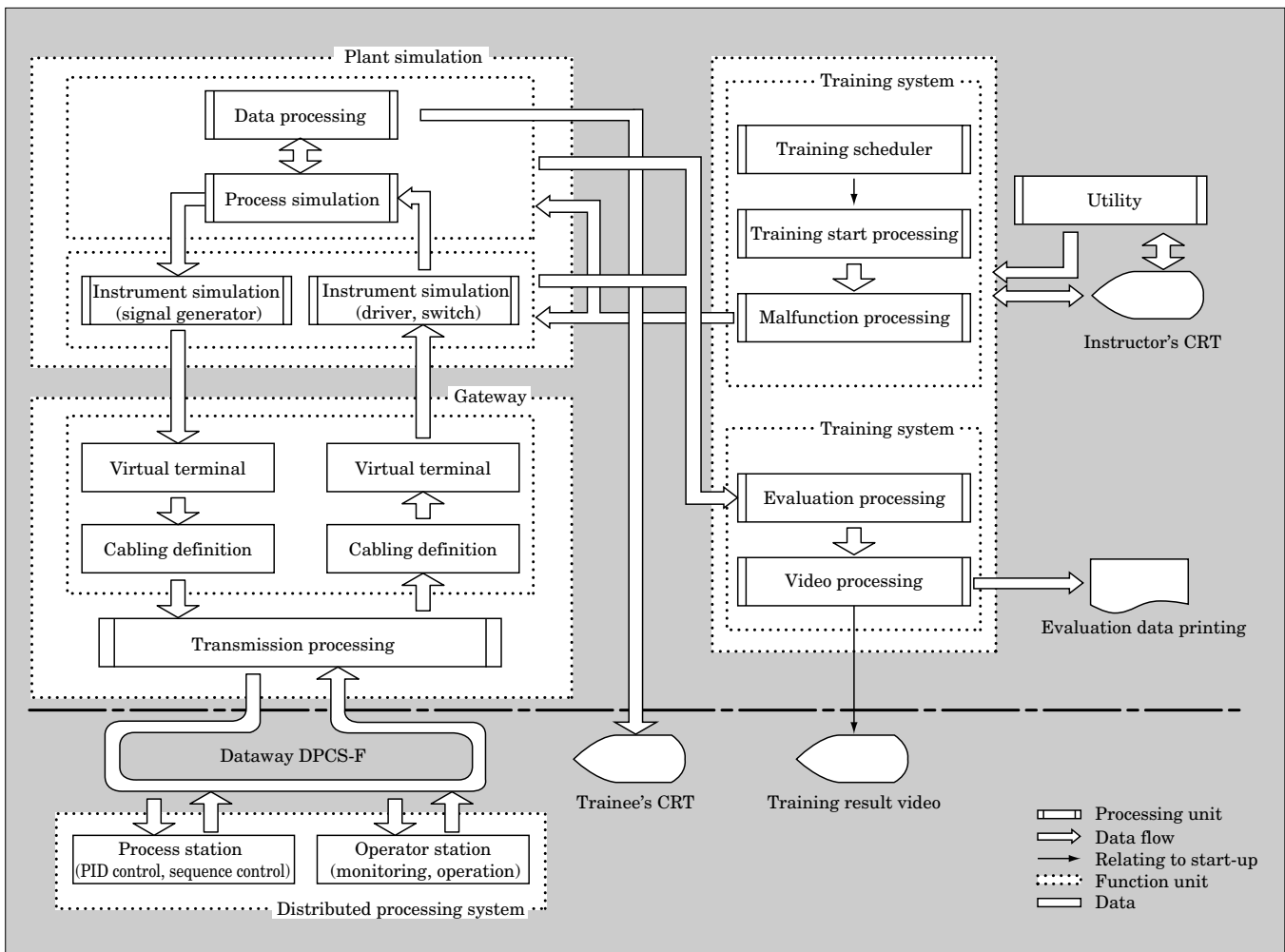


Fig.3 Software configuration of the plant simulator



the actual DCS. The trainee controls the plant from the DCS screen in the same manner as actual operation. The object plant is simulated as a plant model in the computer, and the trainee is trained as if he were controlling the actual plant.

Additionally, the plant simulator has a terminal for the instructor to control and evaluate the training. Figure 2 shows the hardware configuration and Fig. 3 shows the software configuration.

### 3.4 Contents of training

The playback function of the plant simulator permits the operator to repeat past training. This makes it possible to confirm improvements in operation technique or to intensively practice certain operations that require skill.

The items for operation training are as follows.

(1) Training for steady-state operation

The following items are examples of training in response to malfunctions in steady-state operation.

- (a) High boiler drum pressure
- (b) High concentration of exhaust gas NOx
- (c) High or low quantity of steam generated
- (d) Hopper bridge

- (e) Commercial electric power bridge
  - (2) Training for serious malfunctions
- The following items are listed as training for emergency and serious malfunctions that halt plant operation.

- (a) Trip of the steam turbine
  - (b) Trip of the gas turbine
  - (c) Trip of the blower
  - (d) Trip of the induced draft fan
  - (e) Trip of the commercial electric power
  - (3) Training for non-steady-state operation
- This training includes monitoring and operation for automatic start-up and shut-down of the plant as well as operation in response to congestion.
- (a) Boiler start-up and shut-down
  - (b) Incinerator start-up and shut-down
  - (c) Steam turbine start-up and shut-down
  - (d) Gas turbine start-up and shut-down

### 3.5 Control function of the simulation

This function combines a plant model with a real plant training simulator system. The plant model is constructed with the program SimuLink<sup>\*1</sup> that runs on MATLAB<sup>\*2</sup>, a numerical calculation and control analysis program, to model and simulate a dynamic system.

Construction of the plant model with MATLAB is described below.

To use a plant model constructed by MATLAB with the simulator, a source code generator program RTW (real-time workshop that runs on MATLAB) produces the C source code.

MATLAB constructs the plant model and produces the C source code for the simulator.

- (1) MATLAB extracts variable names used by the plant model and generates the block name table. This block name table links the variables of the plant model with those of the simulator.
- (2) The C source code generated by MATLAB can be activated with Windows NT<sup>\*3</sup>.

This plant simulator system executes items (1) and (2) above.

### 3.6 Control function for training

This control function performs operation and settings by the instructor.

#### 3.6.1 Operation by instructors

- (1) Operation function for training

The time span, that is the progress speed of the simulator, can be selected for training from 1/10 to 10 times the actual speed. The state of the training model is changed with operation buttons for start, stop,

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\*1 MATLAB: A registered trademark of The Math Works. Inc., USA

\*2 SimuLink: A registered trademark of The Math Works. Inc., USA

\*3 Windows NT: A registered trademark of Microsoft Corp., USA

pause, restart, and playback. In addition, the operation function can perform training by generating malfunctions via manual operation from the instructor instead of a standard training scenario.

- (2) Instructor's name control function

This control function selects and adds instructor's names, and also keeps track of the related trainee's names.

- (3) Trainee's name control function

This control function selects and adds trainee's names and also keeps track of related training results, evaluations, and scenarios.

- (4) Plant model control function

A file name which the actual system can use and control is selected and specified as the model for the plant simulator.

- (5) Training scenario control function

This control function sets the training scenario for each model and can sequentially generate malfunctions corresponding to each training item. The control function also keeps track of the names of the training scenario and selects and executes the training scenario.

The instructor can also generate malfunctions and execute training by selecting only the initial state, instead of using the training scenario.

- (6) Malfunction control function

This control function displays a list of malfunctions for the selected plant model and training scenario, and also adds or deletes the malfunctions. (These are additions or deletions to the training scenario, not the plant model.)

- (7) Initial state control function

This control function selects an initial state for each plant model and training scenario. This function obtains data for the initial state by using the spot saving function after starting the plant model and establishing a stable state.

- (8) Trend display function

This display function displays the trend graph of process variables showing the operation of this simulator and operation variables that the trainee manipulates.

#### 3.6.2 Operation by trainees

The trainee is basically trained according to the training scenario that the instructor has planned. Training results are evaluated at the end of training by comparison of the trainee's changes in parameters during training with operation of the model after training.

- (1) Training operation setting

In training which uses DCS, the amount of operations is set the same as for DCS.

For stand-alone use, a simple screen set by the personal computer or a screen simulating the DCS is used.

- (2) Trend display function

This display function displays the trend graph of process variables showing the operation of this simula-

tor and operation variables that the trainee manipulates.

### 3.7 Support function for training evaluation

This function supports training evaluation by the instructor.

#### 3.7.1 Operation of instructors

##### (1) Evaluation function for detecting malfunctions

This function extracts the time from generation of a malfunction to detection as an evaluation index and evaluates the training results for detecting malfunctions.

##### (2) Extraction function for model operation

This function extracts the model operations that the instructor performs for each training scenario. Training results are evaluated by calculating the deviation in the amount and timing of operations by the trainee from those of the model operations by the instructor.

##### (3) Evaluation function for process behavior

This function sets the variation tolerance for each process variable. The training results are evaluated by measuring the frequencies that exceed the variation tolerance, as an evaluation index. Minimum and maximum values of the measured variations are also displayed.

##### (4) Advice regarding the training results

This function provides a format for advice based on the training results. This advice consists of an objective evaluation of above items (1) through (3) and comments that the instructor enters.

##### (5) Generating a training scenario

The function extracts the mistakes made by the trainee from the training history to create a training scenario.

#### 3.7.2 Operation by the trainee

##### (1) Display function for evaluation of operation training

This function evaluates and displays the results of operation training by the trainee.

## 4. Conclusion

Created as a mathematical model of a plant, the plant simulator uses computer simulation to realize various training not possible in a real plant. The author wishes that the plant simulator introduced in this paper will evolve to different instrumentation and control systems. Fuji Electric will continue to propose optimal and viable systems amiable to both man and the environment.





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