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APPLICATION OF PROGRAMMABLE CONTROLLER TO INDUSTRIAL PLANT

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1. FOREWORD

Application of the programmable controller (PC) to steel, paper, and other industrial plants began in the first half of the 1970's with the sequencer based on arithmetic and logic operations. Higher performance, higher speed, and higher capacity of processing functions, including numeric operation and data operation, were accompanied by a steady quickening of its popularity and today it occupies an indispensable position in plant control. Moreover, recently, filling out of transmission system and man-machine interface functions has progressed at a fast pitch with the demands for distribution of control and concentration of information. How the PC is applied to industrial plants recently, based on these conditions, is outlined here.

2. PC APPLICATION CONCEPT

2.1 Position of PC

With steel plants and paper plants, there is also a PC stand-alone system for small scale plants. But many are the hierarchical system shown in *Fig. 1*. This hierarchy is grouped into function levels.

(1) Industrial engineering level

Has overall plant production planning, process management, etc. functions.

(2) Process control level

Has optimal scheduling calculation (rolling process set-up calculation, etc.) and other consolidated operation and supervision functions.

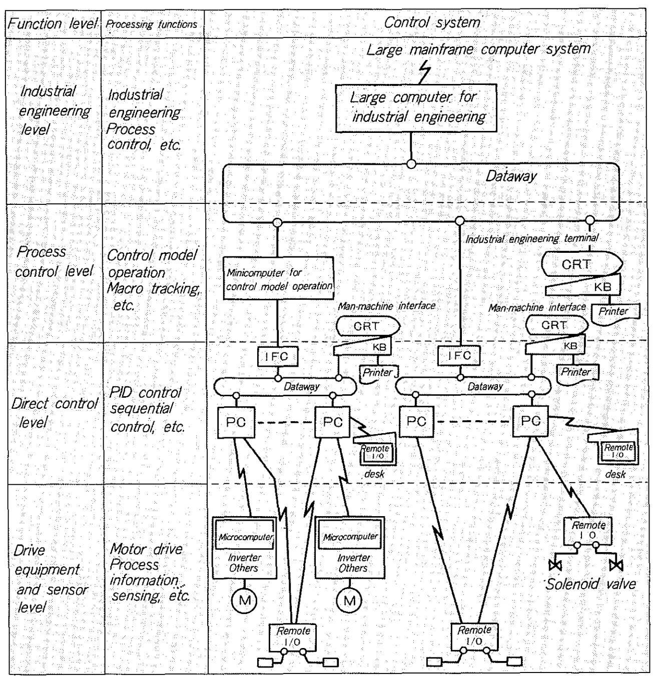
(3) Direct control level

This level directly controls equipment and facilities. The PC is a controller of this level. This level has positioning control, tension control, and other PID control and sequential control functions. A programmable monitoring and control system with CRT (PMS) is used as the man-machine interface.

(4) Drive equipment and sensor level

This level has equipment drive and process information sensing, and other plant and equipment system interface functions based on control commands.

Fig. 1 Hierarchical control system



With development of microelectronics as the background, the functions which are processed at each level are expanding and there is a trend toward processing of functions processed at a high level in the past at a lower level.

2.2 PC application policy

The application of PC to industrial plants must be studied from various standpoints such as high performance, high quality, economy, high maintenanceability, and short delivery time. Fuji Electric plans to develop PC applications based on the following policy:

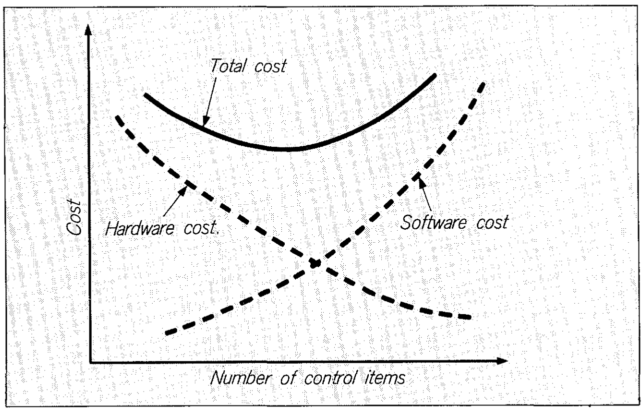
(1) Introduction of new technology

Handling and optimum control by digital control and other advanced control are introduced positively for effective use and higher performance of PC.

(2) PC function load sharing

Excessive concentration of control functions is avoided

Fig. 2 PC cost



and adaptability in PC units planned.

The incorporation of functions per unit PC as far as the PC functions permit is advantageous from the standpoint of hardware cost. When the total cost with the software, from software design to field testing, is considered, the optimum point is shown in *Fig. 2*. This consideration is indispensable from the stand points of copying with improvement and renovation of plant facilities.

(3) Use of man-machine interface

Regarding PMS as a man-machine interface, the division of use with the operation desk from the standpoints of operation and supervision is clarified and sharing of the load is centered about the setting and monitoring functions. Besides plant control functions, this PMS will be filled out by installing a maintenance monitoring function from the standpoint of improving plant maintenanceability.

(4) Interface with drive equipment and sensor level

Standardization of the drive equipment level is planned and plant-oriented functions demanded by the facility are processed by PC. Further, I/O devices are distributed by housing in the operation desk, etc. and the sensor receiving panel, solenoid valve panel, etc. interface panel is eliminated by I/O devices with excellent high power and environment resistance.

(5) Improvement of software production technology

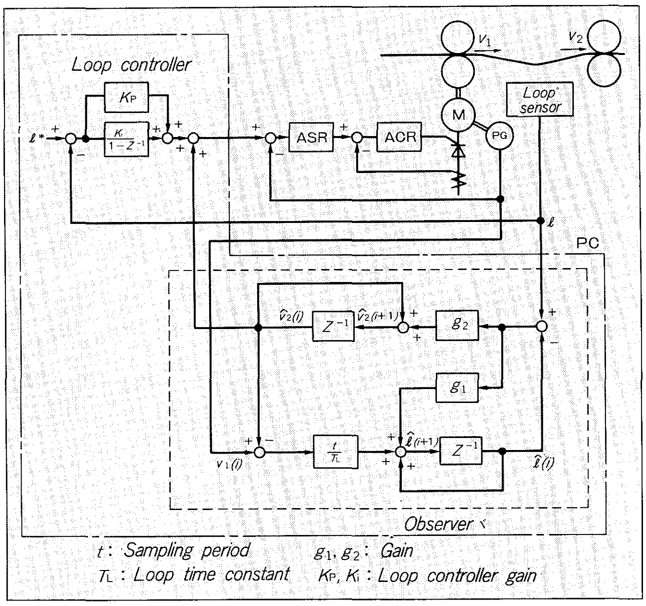
Due to the expansion of the field of applications of the PC, increase of the demanded functions, and short delivery time factors, improvement of software production efficiency and improvement of quality have become problems even with PC. In order to cope with this, a software production support system by computer was developed and operated. The main support functions current operating are:

(a) Intelligent reference and guide system of software
(b) Registration of software library and software reuse
(c) Interactive design
(d) High quality document output (kanji comments, cross reference, etc.)

3. APPLICATION OF PC TO INDUSTRIAL PLANTS

At industrial plants, the demand for high quality products is accompanied by a demand for PC software with advanced functions. Fuji Electric followed these trends and has promoted development of software using digital control theory, in particular, of the modern control theories for feedback control using a PC. Since this software is not for digital control as an approximation of continuous-time series, the sampling period can be extended to two or three times that of conventional systems and the effective use of calculation time can be planned. An example of application of observer theory and optimal control theory in discrete-time theory to an industrial plant is described below. To an industrial plant at a scattered time series is described below. Control, which is another feature, is also introduced.

Fig. 3 Loop control using an observer



3.1 Application of the PC to a steel plant

3.1.1 Loop observer

To improve the product accuracy in bar and rod rolling, etc., rolling with the tension or compression acting on the rolled material as zero is demanded. At the finishing train, a loop is formed between stands and free tension is obtained by keeping this loop constant. The loop length at biting of the rolled material to the rolling mill changes. The observer shown in *Fig. 3* suppresses loop length changes by estimating the rolled material speed of the opposite stand and applying forward compensation to a speed control system according to the estimated value.

3.1.2 Use of optimal regulator

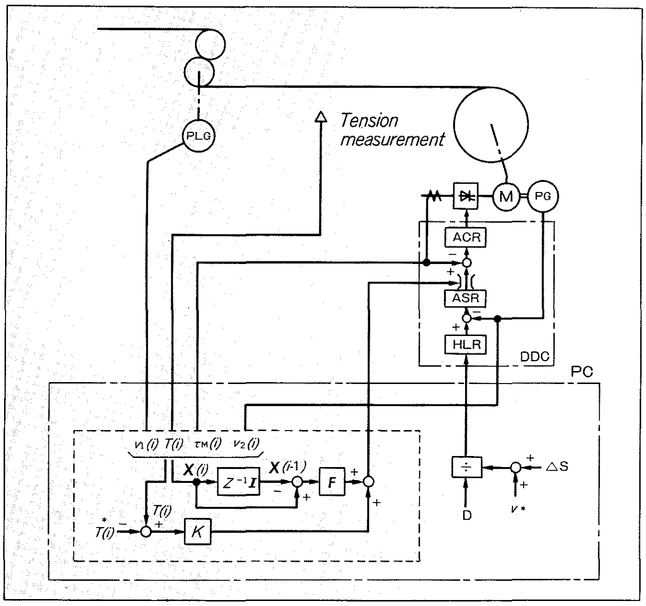
(1) Reel tension control

In cold rolling, etc., tension control of the tension reel that winds the rolled sheet into a coil and the payoff reel that unwinds the coiled sheet often generates a tension vibration of several Hz. The control system shown in *Fig. 4* attempts to control this tension vibration by state feedback and is effective in controlling tension vibration of several Hz that is impossible with conventional control.

(2) Shape control

As described in paragraph 3.1.1, to improve the product quality in bar steel rolling, the trend is toward free tension rolling at both the intermediate train and roughing train. In recent years, a trend toward manufacturing more accurate products by rolling stand roll gap control. The control shown in *Fig. 5* is shape control combining roll gap control and free tension control. This system produces a shape closed to the target shape by taking the tension, roll gap, roll speed, motor torque, and delivery thickness deviation as state variables and performing stand drive motor speed correction and roll gap correction by state feedback and can product high quality products.

Fig. 4 Reel control using optimal regulator



3.1.3 Conveyance control

With the reheating furnace at the process before the rolling process, recently, conveyance control is being performed by dividing the interior of the furnace into several zones, and there is a trend toward efficient heating of many kinds of materials simultaneously.

This makes conveyance control of the material in the furnace difficult and at times, the number of conveyance patterns can reach several hundred. There are many cases in which assuming all these patterns and designing the software is difficult.

This is dealt with by building a system like that shown in *Fig. 6* by software. When control divided into four levels of power control level, cycle control level, zone control level, and general control level and a start signal is input to each level from a high level, the software checks the restriction conditions for material conveyance corresponding to the level for each level and when the conditions are established, outputs a start signal to the lower level. Since the software has such a structure, the machinery can heat and convey the material according to the state inside the furnace.

Another feature is that by paying attention to the restriction conditions only, the software designer can design

Fig. 5 Steel rolling control using optimal regulator

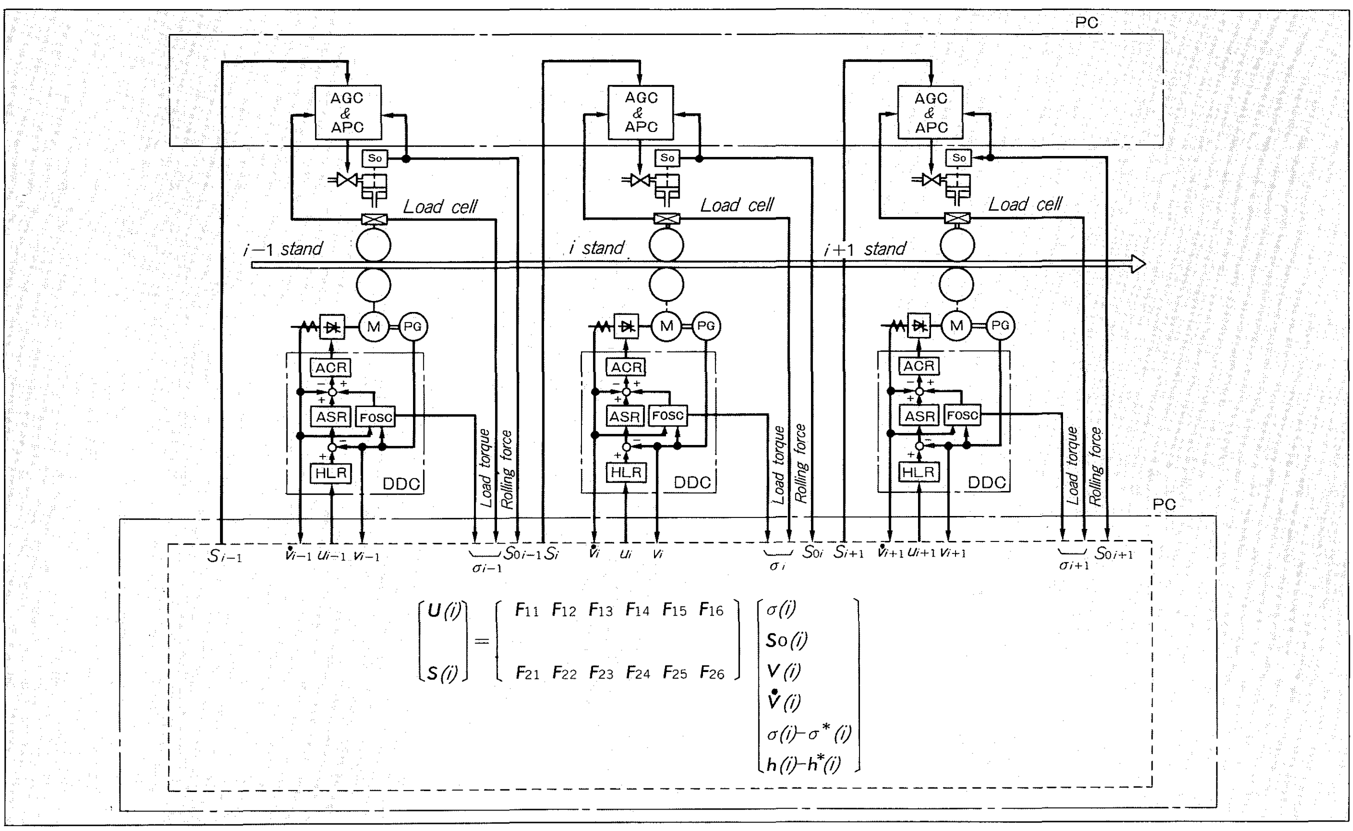


Fig. 6 Conveyance control with hierarchical system

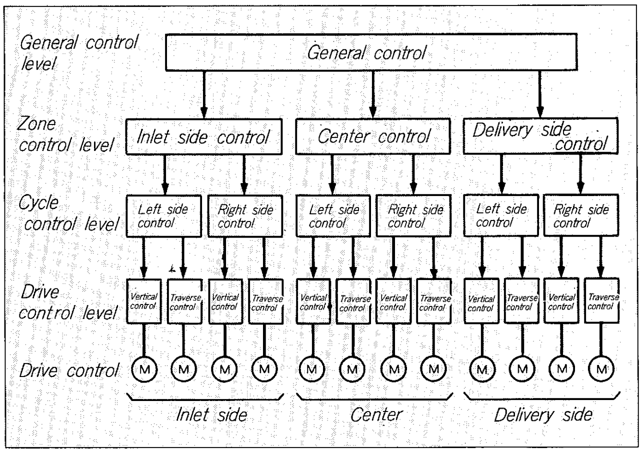
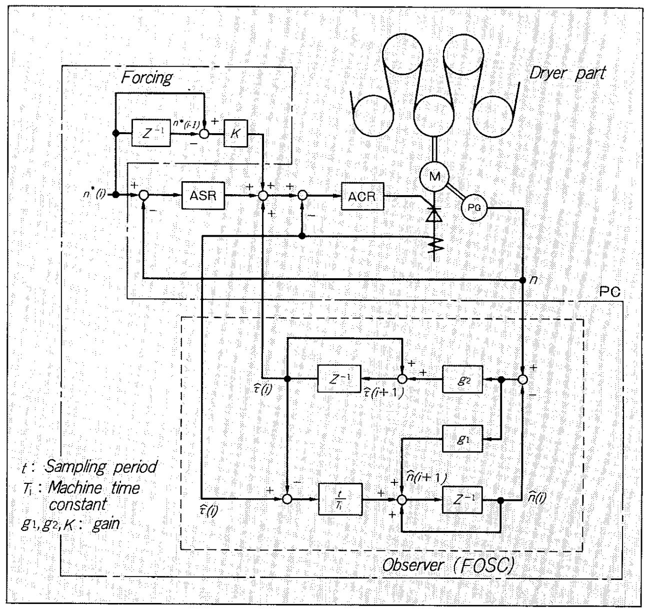


Fig. 7 Speed control using an observer



software without having a detailed knowledge of the material conveyance procedure.

3.2 Application of PC to paper plant

3.2.1 Impact drop control observer

With a paper making machine, especially at the large moment of inertia dryer, calender part, speed changes and recovery time at breaking and threading obstruct operation. Therefore, speed changes at breaking and threading are suppressed by using an observer. A speed control system using an observer is shown in *Fig. 7*. The observer suppresses speed changes and shortens the recovery time by estimating the load disturbance and applying feed forward correction to the current control system according to the estimated value. Moreover, for speed setting, a forcing command is given and speed trackability is increased.

4. CONCLUSION

Application of the PC to the current control system was introduced. In the future also, the PC will be widely used as a direct control level controller and its importance will increase. Fuji Electric will continue it ceaseless efforts in the PC application of new technology, improvement of software production technology, etc. and will offers high performance and high quality systems matched to the needs of increasingly complex industrial plants.