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DEMAND CONTROL SYSTEM FOR SUBSTATION WITH MELTING ARC FURNACE LOAD

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I. INTRODUCTION

Demand control refers to monitoring of the total amount of power used by all of the power users at a receiving point and effectively controlling the users' load within the range that the amount of power contracted with the power company in each demand period (15-60 minutes) is not exceeded.

Among power users including melting arc furnaces, the amount of power consumed by melting arc furnaces is very high, reaching about 500kWH per ton. There are also many periodic changes in the operating cycle of a melting arc furnace. Therefore, demand control is very important for the effective input of the maximum power within the contracted power range.

Especially at the present when there is great stress on the effective utilization of power, there is a demand for equipment which has a higher level of prediction, monitoring and control functions so that the power used by melting arc furnaces can be predicted and their operation can be controlled.

Recently, a 100t arc furnace for melting (furnace transformer capacity: 60MVA) has been added at the Funabashi Steelworks and Fuji Electric provided demand control equipment in the receiving point of the plant power reception and distribution network mainly for the new arc furnace and the existing 50t arc furnace (furnace transformer capacity: 30MVA). This equipment uses the Fuji minicomputer PUC-10 with a software system developed in cooperation with Nippon Kokan. An outline of the equipment is given here.

II. SYSTEM CONSTRUCTION

Fig. 1 shows the construction of the demand control system. This system is centered around a PUC-10 minicomputer with a central processing unit and includes an operator's console where all operations, displays, settings and alternations are performed; a digital clock with BCD output for demand time monitoring; a system typewriter for various types of printouts and switch panel which serves as an interface panel with exterior equipment. The system performs demand control by operating automatic arc furnace operating equipment located in the site operating rooms for the 50t and 100t arc furnaces. The specifications and functions of each of these components are described in the following sections.

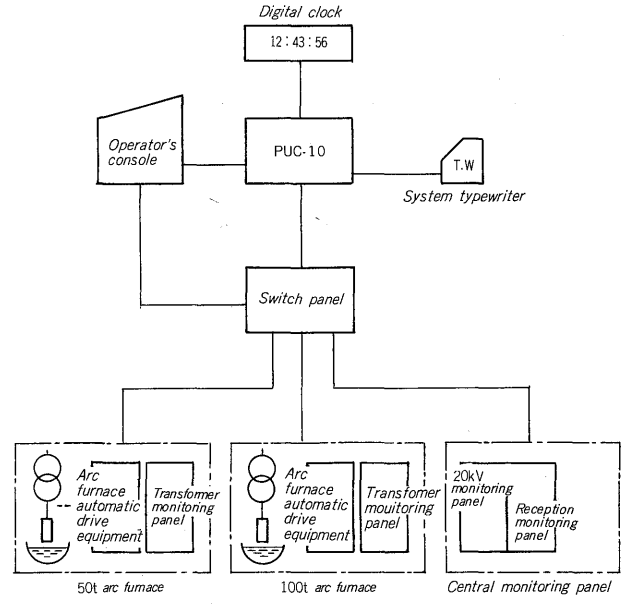

Fig. 1 Demand control system

1. PUC-10

The PUC-10 was especially developed for process control and data processing mainly by means of a stored program type central processing unit from the standpoints of economy and reliability to replace the systems consisting of relays and contactless logic elements which were formerly used in small scale systems. The PUC-10 system is accomodated in one block together with the RTC process input/output device and the central processing unit.

Table 1 shows the specifications of the PUC-10 system and *Figs. 2* and *3* an outer view and the structure respectively.

2. Operator's console (demand control desk)

This console serves as the interface between the system

Table 1 PUC-10 specifications

	Item	Functions
System		Program memory type digital controller
Memory equipment	Maximum memory capacity	Magnetic core
	Word length	16 bits + 1 parity
	Access units	1 word
	Cycle time	1.9 μs
	Maximum memory capacity	4k words (1k word = 1.024 words)
	Minimum memory capacity	2k words
Operation control	Elements	TTL, MSI
	Operational system	Parallel binary method, negative numbers indicated by complements, fixed point
	No. of commands	26
	Address system	Direct address
	Interrupt level	Hardware = 1, external = 1, Total 2
	Operation speed	Addition/subtraction = 3.9 μs
	Register	1
Functions	Memory protection	Possible in 1k word units. Interrupt occurs during obstruction
	Command execution treatment	Command execution time monitored, external report if abnormal
	Power interruption treatment	Automatic stand-by and restarting
	Operation	Operation from panel of external equipment
Auxiliary memory	Control system	Interface mode
	Maximum data transmission speed	25k words/sec.
	No. of connected units	1
Input/output devices	Control system	Program mode
	Maximum data transmission speed	100k words/sec.
	Connected devices	RTC standard device
	No. of connected units	128
Specifications	Temperature	0 ~ 40°C
	Humidity	20~80% RH
	Input power supply	AC 100V, 1ϕ, 50/60 Hz
	Required power	Approx. 0.3kVA (only central processing unit)

and the operator and has the following functions:

(1) Various settings required for demand control,
(2) Digital indication of real, predicted and contract values (demand values) of power used.
(3) Guidance display of various input times calculated from arc furnace input predictions made by the Pattern I control system described in the next chapter,
(4) Alarm displays related to the control results and the PUC-10 hardware),
(5) Various types of PBL.SW. for system operations,
(6) "Control" and "Exclusion" PBL. With the "Exclusion" push-button, the arc furnace trip signal due to demand control is cut by the switch panel.

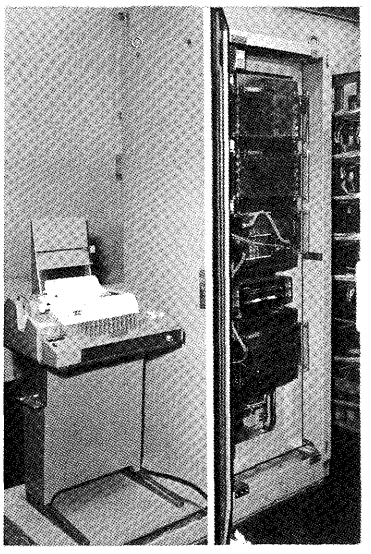

Fig. 2 Outer view of PUC-10

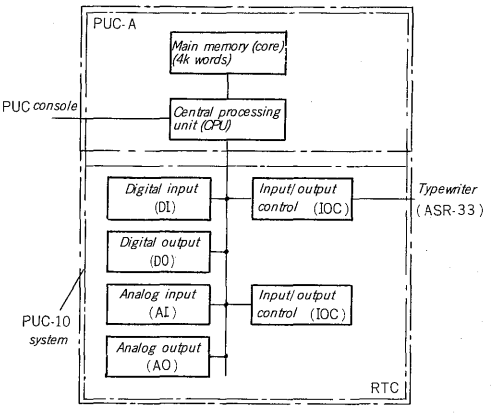

Fig. 3 PUC-10 system

3. Switch Panel

This panel receives signals from both the PUC-10 system in the electrical room and external equipment. It contains Teleperm insulation converters, auxiliary relays, etc. which perform level conversion of analog output of the input power set by the automatic arc furnace operating equipment located in the electrical furnace operating room. With the exception of part of the signals from the operator's console and the digital clock, all of the signals of the PUC-10 and from the exterior pass through this panel.

4. System Typewriter

This typewriter is used for automatic print-out during arc furnace trip signal output by demand control, optional printout during demand control and confirmation printouts of various types of set values from the operator's console used in demand control. It also has teleprinter and tape puncher functions required initially or during debugging. An example of a print-out list is shown in Table 2.

Table 2 Print-out list

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TEST TYPE OUT

TUE-WEEK  13:52,30
PTN 2
FUR
SET  580
NOW  341
END  389
CONDITION
 50T CUT
100T MAN

SETTING VALUE

FRI-WEEK  10:23,15
00-11H
WEEK  860  860  860  860  860  860  860  860  580  580  580  580
HOLI  860  860  860  860  860  860  860  860  860  860  860  860

12-23H
WEEK  580  580  580  580  580  580  580  580  580  580  860  860
HOLI  860  860  860  860  860  860  860  860  860  860  860  860

PTN  HOLI WEEK WEEK WEEK WEEK WEEK WEEK
      F11  F12  F21  F22  F31  F32   F4  F4T(M)
 50T  250  250  250  250  250  250  150   20
100T  150  150  150  150  150  150  100   20
BASE  100
FLICKER 0.38
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5. Digital Clock

This is a high accuracy crystal clock with a 6-column 7-segment display system and a liquid crystal cell which performs time detection of the important demand cycles in this system. Signals are transmitted to the PUC-10 by means of the BCD output. By means of the built-in battery, this clock can continue operation during a power interruption of 72 hours.

6. Arc Furnace Automatic Operation Equipment

This equipment is used for the optimum and automatic melting of scrap in the melting arc furnaces. The required amount of power input is calculated from initial setting of scrap input, steel grade, etc. There is automatic selection of elements such as voltage and current set in accordance with the arc furnace conditions and the optimum melting can be achieved.

III. OUTLINE OF THE SYSTEM

In melting arc furnaces, there is little effect on the product quality even when the power supply to the furnace is interrupted for short periods during the melting period other than the smelting period. However, continuous power is required for line processing in continuous casting and rolling except for arc furnace processing and stable and continuous power supplies are indispensible conditions. Therefore, demand control in melting arc furnace plants is essential so that there is no effect on the power load except for the arc furnaces. Therefore, it is necessary to consider the output period of the arc furnace trip signal in keeping with the integrated value of the amount of power due to the power load (known as the base amount of power). In this system, this base power is set from the operator's console by means of actual values used in the past in the 30 minutes of the first half of the demand period. In the 30 minutes of the last half, it is obtained by a gradient prediction as a shifting average from the amount used during the first 30 minutes. The trip level shown in *Fig. 6* is obtained by subtracting the base power obtained in this way from the demand power.

Thd main alarm signals given out in demand control are as follows:

1) 1st stage demand

When it is considered that the demand amount will be exceeded if conditions continue as they are only from an alarm, output is sent to the arc furnace being operated by the automatic operation equipment.

2) Load limit

A load limiting instruction with the same contents as the 1st stage demand is given to the arc furnace which is not being operated automatically.

3) 2nd stage demand

This is an alarm only for arc furnace tripping and is given out only under the following conditions:

(1) when the power used is over the trip level,

(2) When the trip level is not exceeded but it is predicted in pattern I described hereafter that the demand will be exceeded.

The control systems are classified into the following three patterns as shown in *Fig. 4* in accordance with whether or not operation uses the arc furnace automatic operating equipment and the length of the demand period.

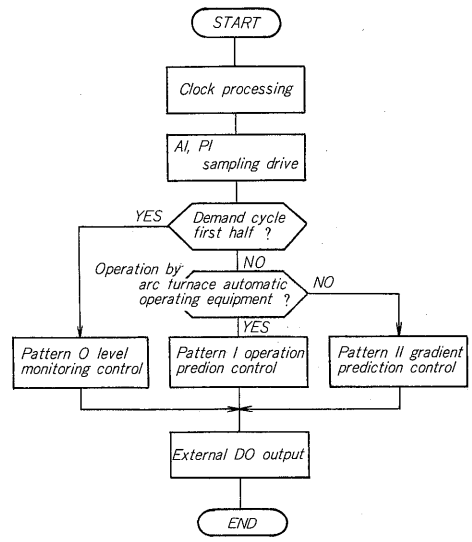

Fig. 4 General flow chart of demand control

(1) Pattern 0: level monitoring and control performed in the first 30 minutes of the demand period

(2) Pattern I: Prediction control of operation performed by interlocking with the automatic operation equipment in the latter half of the demand period. Input guidance is also given by means of the input prediction calculation for the furnace side operator.

(3) Pattern II: Gradient prediction control according to the calculation of the rate of increase of the power used as a Pattern I back-up when

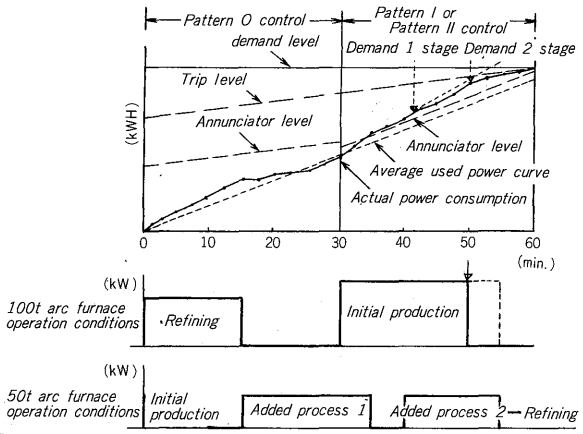

Fig. 5 An example of demand control

the automatic operating equipment is not used.

Each of these patterns are outlined below. An example is shown in *Fig. 5*.

1) Pattern 0 control

This control is performed in the first 30 minutes of the demand period. There is monitoring to determine if actual amount of power used exceeds the preset annunciator level or the higher trip level. If either of these levels are exceeded, the "1st stage demand" or "2nd stage demand" alarms are given out. The "2nd stage demand" is a trip signal which cuts the power input to the arc furnace.

2) Pattern I control

This pattern is the core of this demand control system. It performs demand control while determining the arc furnace operating conditions by interlocking with the automatic operating equipment and keeping the effects on product quality due to power cuts during the arc furnace smelting period to a minimum.

This pattern performs input prediction calculations for each furnace and also has the function of providing guidance to arc furnace operating personnel concerning the optimum furnace operating time. The control methods are as follows.

The amount of power to be used by the furnace during the current melting or smelting until completion of melting or smelting is calculated from the data from the arc furnace automatic operating equipment and the arc furance operating time. The predicted amount of power used is obtained from adding the above amount of power to the power used to date. Then, it is determined whether or not this predicted amount exceeds the demand amount. When it is found to be in excess, there is an automatic selection of the alarm "1st stage demand", "load limit" and "2nd stage demand" according to the arc furnace operating conditions at the time (initial charge, 1st additional charge or 2nd additional charge, smelting) and the furnace is tripped.

Under this control pattern, it is possible to calculate the time for which the operation which will not exceed the demand amount if the furnace which is stopped is started after a certain number of minutes when it is determined that the predicted amount of power used will not exceed the demand power obtained in the prediction control described above. The results of the calculation are digitally displayed in minutes and serve as an operation guide for the furnace side operators. Simultaneously, a digital display is also given on the operator's console. From this display, the operators can know the waiting time immediately. *Fig. 6* shows a flow chart of Pattern I control.

3) Pattern II control

When the arc furnace is operated munually, Pattern I control in the above section becomes impossible. This control system serves as a back-up in such cases.

The increase rate of the power used (power) obtained from a pulse count of the power used at the receiving point is calculated and the final amount of power used at the time when the demand period is completed under the same conditions is predicted. This is combined with the same level monitoring function as in Pattern 0 control. Alarms "1st stage demand" or "load limit" are given out according to conditions at the time or the "2nd stage demand" alarm is given and the arc furnace power is cut.

This control system serves as a back-up for Pattern I control and it also serves to assure sufficient demand control when only this pattern is in use.

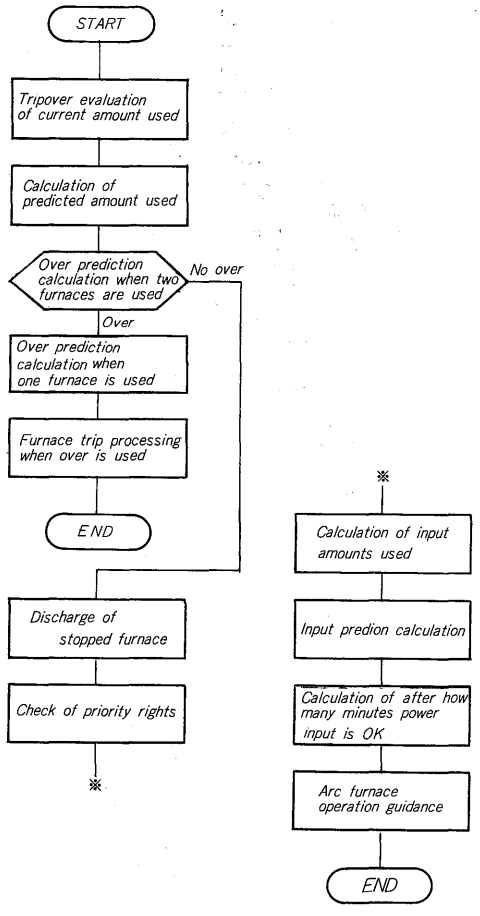

Fig. 6 General flow chart of pattern I control

IV. CONCLUSION

This article has given an outline of demand control using a minicomputer as the main control equipment for receiving and distribution equipment in melting arc furnaces. In this example, there were two arc furnaces but even when there are more, this demand control system can be expanded functionally on the basis of the same methods. When there are several arc furncaces, complex determinations concerning the effective use of contract power and the optimum furnace operation become indispensible. In such cases, the Pattern I control introduced here becomes especially effective and the responsibilities of the operators can be greatly decreased.

In conclusion, the authors with to than all those persons concerned in the Funabashi Steelworks for their guidance and cooperation.