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COMPUTER CONTROL OF THE SHIN-NAKACHIYAMA POWER STATION OF THE HOKURIKU ELECTRIC POWER CO., LTD.

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I. INTRODUCTION

Recently, there has been a tendency for the reliability and performance of computer control systems to increase while the price decreases. For this reason, it is considered that the application range of such systems will spread from control in the iron and steel industry and in chemical plants to measuring system components and will continue to grow in the future.

In the electric power system field, computer control systems have been used from before in automatic distribution systems in central distribution offices (CDO) and in control systems of thermal power stations. Recently there have also been cases of practical application of centralized control systems for power stations and substations.

In automatic dispatching systems, special devices for data processing, dual systems of computer hardware and hierarchical control systems are employed in order to maintain the correct level of control characteristics. For controlling water system, it is necessary thoroughly to grasp the local and natural conditions and have countermeasure for stopping the central equipment. For this purpose there is tendency to instal small control-computers hierachically in central electric stations.

The Hokuriku Electric Power Co., Ltd. already has automatic frequency control (AFC) with a special computer as part of its automatic distribution system. The equipment delivered in this case has been designed and manufactured so that the various types of functions necessary for eliminating normal monitoring in each substation are in harmony with the total AFC taking special control conditions of the Arimine water system into consideration. It is a hierarchical system which forms a part of the automatic distribution system. The main functions are as follows:

(1) Water level control of regulating basin of Shin-Nakachiyama power station.
(2) Distribution power control in the Wadagawa No. 2 power station and the Shin-Nakachiyama power station.
(3) Operation according to water input in the Shin-Nakachiyama power station.

This article gives an outline of this equipment and these control systems.

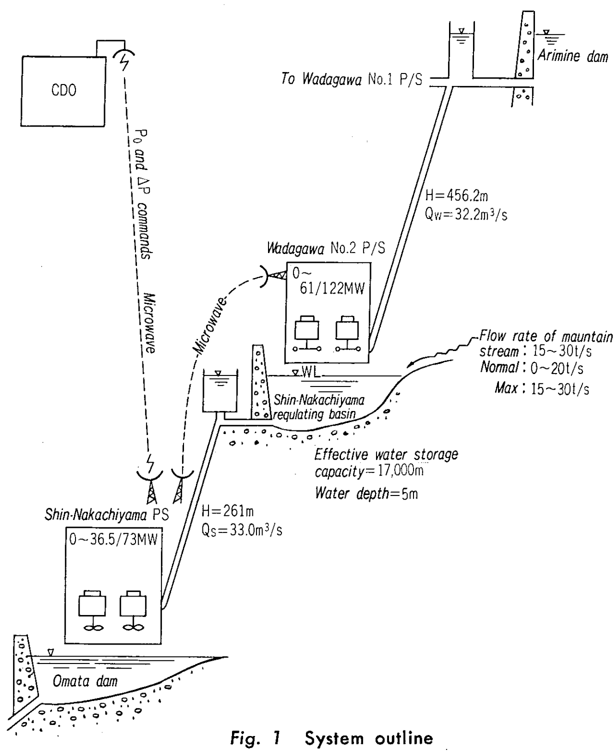


Fig. 1 System outline

II. SYSTEM OUTLINE

This system is located in the Shin-Nakachiyama power station of the Arimine system which is a branch of the Joganji river system. The main computer is the FACOM R and output instruction distribution is performed for the controlled stations, the Wadagawa No. 2 P. S. (122 MW) and the Shin-Nakachiyama P. S. (73 MW).

Fig. 1 shows an outline of the water route. As can be seen in the figure, the stations controlled are connected in series via the very small capacity Shin-Nakachiyama regulating basin. Therefore, this regulating basin (the effective storage capacity is only 17,000 m³ which is equivalent to the maximum output from the down stream Shin-Nakachiyama power station for only 5 minutes). can be said to be the connection tank for both power stations. The water level of this regulating basin is increased or decreased by the difference of water intake flow between the Wada No. 2 P. S. and the Shin-Nakachiyama P. S. as well as the integration of the mountain stream flow. Therefore, this water level is monitored at normal times and regulation is performed to ensure the safety level for both stations. This is very difficult in respect to the automatic frequency control (AFC) in the central dispatching control station.

This system overcomes the difficulty effectively and performs control so that the most effective utilization can be made of the mountain stieam flowing into the Shin-Nakachiyama regulating basin. Completely unattended control is possible for the controlled stations.

III. COMPONENTS OF THE COMPUTER CONTROL SYSTEM

(1) Centıal processing unit FACOM R
(2) Real time control unit
(3) Typewriter
FACOM Writer F 805 A
(4) Operator's console
(5) Relay unit
(6) Power source unit (with AVR and electrostatic shield plate)

1. Central Processing Unit

(1) Type	FACOM R
(2) Word length	16 bits+parity bit
(3) Cycle time	1.5 μs
(4) Core capacity	4 kW
(5) Instruction number	28

2. RTC Input/Output

(1) Interruption input	2 points (16 bit contact input)
(2) Analog input	8 points (0~5 V)
(3) Code input	2 points (32 bit contact input)
(4) Contact input	80 points
(5) Analog output	4 points (0~50 mA)
(6) Code output	5 points (80 bits contact output)
(7) Contact output	64 points

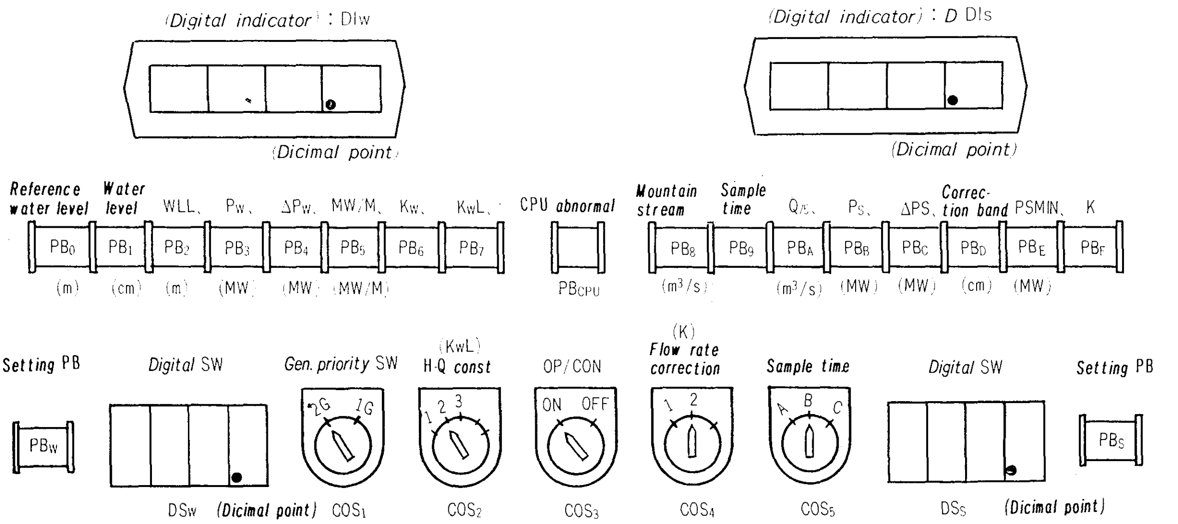
3. Oprreator's Console

A front view of the operator's console is shown in *Fig. 2*. As is evident from the figure, the data required for the control system can be on-line constant modified by the switches and buttons on this operatator's console. It is also possible to select and monitor optionally the required data using these switches and buttons. *Fig. 3* is a block diagram of the computer control system.

IV. PROGRAM OUTLINE

The applications of this computer system can be divided into two systems: programs started by interruption at set times from the RTC clock device and programs started by command signals of sharing from the exterior. The details of these programs are as follows.

(1) Reading of input data
(2) Calculation of working flow rate of both stations
(3) Calculation of average water level
(4) Checking of water level
(5) Constant modification by number of generators operating



$PB_0 \sim PB_F$:	Selective buttons	DS_W, DS_S:	Date setting switch
$COS_1 \sim COS_5$:	Changeover switch	PB_{CPU}:	Indicator for detecting abnormal
DI_W, DI_S:	Indicator		
PB_W, PB_S:	Setting buttons for interrupt command		

Fig. 2 Frontview of operator's console

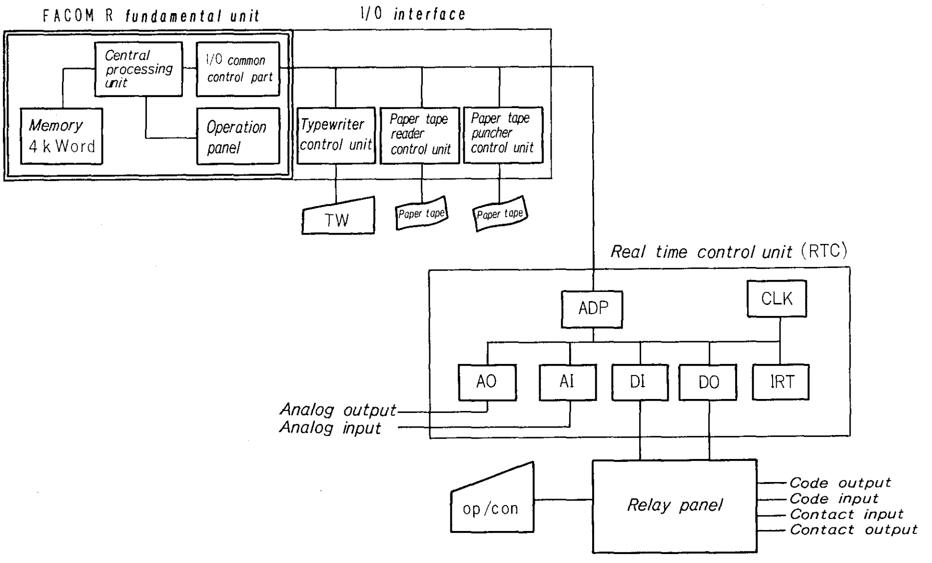


Fig. 3 **Blook diagram of computer control system**

(6) Selection of operating mode
(7) P_0 distribution
(8) ΔP distribution
(9) Operation control for water input
(10) Distribution calculations when external conditions are abnormal
2) Programs started by exterior interruption
(1) Interruption during constant setting from operator's console

A brief description of the main arithmetic parts of these programs is given below.

1. Calculation of Average Water Level

The water level of the Shin-Nakachiyama regulating basin is detected by the float type water level transmitter located on the gate side and the results are transmitted to the central processing unit by the CDO. However, since the measured data are changed several centimeters over the normal value by ripples or rolling from the upstream station (the Wadagawa No. 2 P. S.), the data can not be used immediately as processing data.

Therefore, the average water level is computed by the following equation and the results serve as computer input.

$$\overline{WL_n}=\overline{WL_{n-1}}+(WL_n-\overline{WL_{n-1}})\,K \cdots\cdots\cdots\cdots(1)$$

where $\overline{WL_n}$: new filtered measured value
$\overline{WL_{n-1}}$: former filtered measured value
WL_n: newly measured value at time of sampling
K: constant

Equation 1 gives the approximate first order lag characteristics and these characteristics are shown by the following equation.

$$t=\frac{\Delta T}{K} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(2)$$

where t: time lag
ΔT: sample time

The main arithmetic part constant K in equations (1) and (2) is a variable constant (0~100%) which can be set optionally in accordance with the water level of the regulating tank. Therefore, a constant water level can be obtained normally even when there is play in the float for measuring water level or when the water level transmission circuit is DOWN.

2. Calculation of Corrected Flow by Water Level and Calculation of Mountain Stream Flow

The mountain stream flow is obtained by the following equation:

$$Q_k=\sum_{t=0}^{t=n}\frac{QSW_t+\Delta WL\cdot KW\cdot L}{n} \cdots\cdots\cdots\cdots(3)$$

where Q_k: calculated value for mountain stream
QSW_t: Q_s-Q_w when each sampling is made
ΔWL: change in regulating tank water level within n sec.
KWL: constant
Q_s: Shin-Nakachiyama P. S. working flow rate (downstream)
Q_w: Wadagawa No. 2 P. S. working flow rate (upstream)
n: mountain stream calculation period

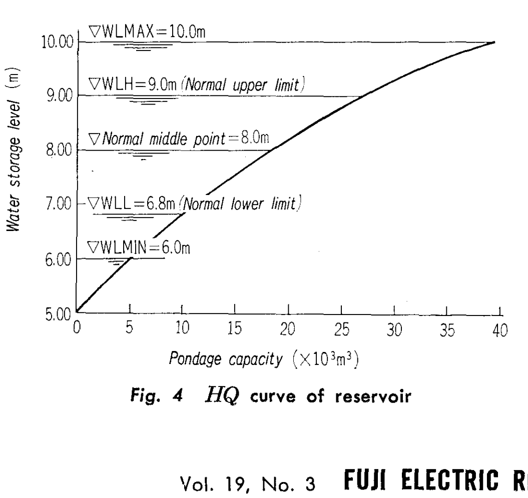


Fig. 4 ***HQ*** **curve of reservoir**

The constant *KWL* in equation (3) shows the relation between the storage water level in the regulating basin (H) and the amount of water stored (Q). It is in the form of the assimilated polygonal line in *Fig. 4* and is used as computer input.

The mountain stream flow changes in accordance with changes in climatic conditions but generally, there are no rapid changes in short periods. Therefore, the mountain stream calculation period in this system is set for several minutes. Changes in the mountain stream calculated values also occur easily because there are transient phenomena such as load shedding in the upstream and down stream stations. In order to avoid this, a blind band and a filter circuit have been added to obtain stable mountain stream calculation results.

There is one more problem in the calculation of the mountain stream flow. In the case of manual control (except one-man control AFC) in the Wadagawa No. 2 P. S., there is the problem of changeover between manual control and AFC control in the water input operation mode (described later). This point has been considered in this system and a smooth changeover is possible between water input operation and simultaneous operation.

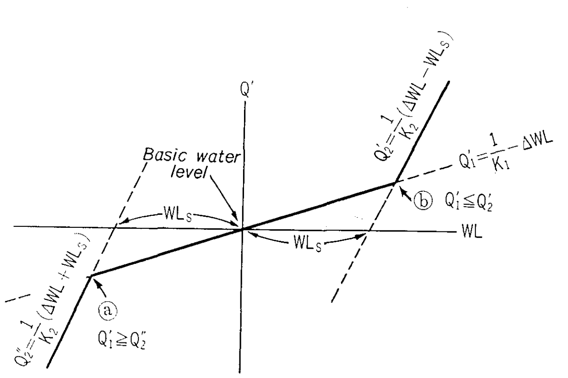
Fig. 5 shows the correction curves of flow quantity. In the figure, Q'_1, Q'_2 and Q''_2 are the corrected quantites and their calculation results are obtained from equation (4) as main factors for regulation of the water level in the regulating basin.

3. Operation Mode Selection

There are two operation modes: the parallel operation mode and the water input operation mode.

1) Parallel operation mode

This is the condition in which output is obtained with distribution instructions from the distribution computer simultaneously to both the Shin-Nakachiyama and the Wadagawa No. 2 power stations. This mode is established under the following conditions.



WL: Water level Q'=Corrected flow quantity
WLs: Corrected flow quantity from K_2 basic water level
K_1: Corrected coefficient 1 (outside setting)
K_2: Corrected coefficient 2 (outside setting)
ΔWL: Basic water level (water level at 0)

Fig. 5 Correction curve of flow quantity

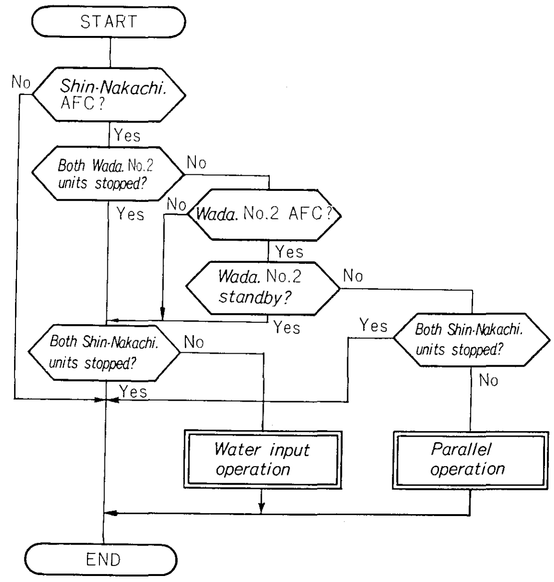


Fig. 6 Flow diagram for selection of operation mode

(1) There is operation of more than one unit in both power stations and the AFC is also in the ON condition.

(2) The Wadagawa No. 2 power station is not in the stand-by condition.

2) Water input operation mode

In this mode, there is automatic operation of the Shin-Nakachiyama power station in accordance with the mountain stream computed value. It arises under the following conditions.

(1) The Wadagawa No. 2 P. S. is completely stopped in the stand-by condition or under completely manual operation.

(2) In the Shin-Nakachiyama P. S., the two units are not both stopped due to a breakdown and the AFC is ON.

An outline of these modes is shown in *Fig. 6*.

4. P_0 Distribution Computation

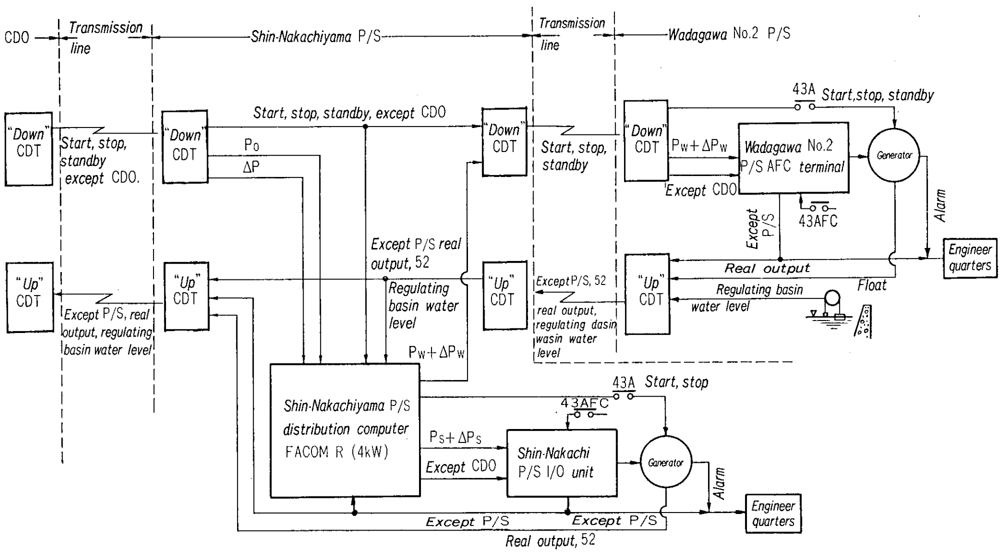
The commands given to the system from the central distribution office are as shown in *Fig. 7*. P_0 (sustended component) and ΔP (fringe component) have separate routes and are applied to both power stations as a sum.

Therefore, the P_0 distribution computation is performed in consideration of the mountain stream and the corrected flow values. The results are dispatched to both power stations and the distribution is calculated by the following equation in such a way that the water level is normally maintained at the standard operation level.

$$P_w = K_w \frac{[P_0 - K_s(Q_k + Q') + K_s \cdot Q_{0s} + K_w \cdot Q_{0w}]}{K_s + K_w} \quad \cdots\cdots(4)$$

$$P_s = P_0 - P_w \quad \cdots\cdots(5)$$

where P_0: CDO command value (sustended



ΔP: COD command (fringe component)
P_0: CDO command (sustended component)
$\Delta P_w + P_w$: Command value to Wadagawa No. 2
$\Delta P_s + P_s$: Command value to Shin-Nakachiyama

Fig. 7 **Control block diagram**

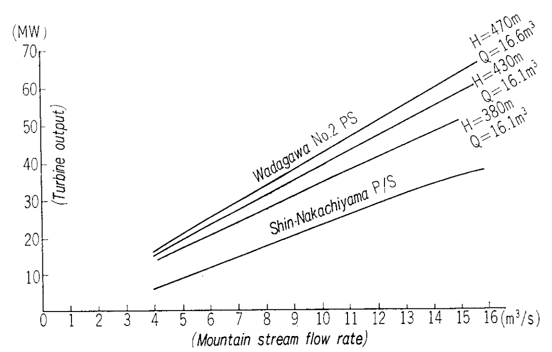


Fig. 8 **PQ curve of power stations**

Table 1 **Outline of power station equipment**

		Wadagawa No. 2 P.S.	Shin-Nakachiyama P.S.
Max. working flow rate	(m^3/sec)	32.20	33.00
Effective head	(m)	456.2	251.0
Upper output	(MW)	61.0×2	36.5×2
Lower output	(MW)	7.0×2	14.0×2
Kind of water turbine		V•P×2	V•H×2
Turbine capacity	(kW)	68,900×2	37,000×2
Generator capacity	(kVA)	70,000×2	42,000×2
Dry season peak output	(kW)	101.0	72.8

component)

P_w: distribution command value to Wada No. 2 P. S.

P_s: distribution command value to Shin-Nakachiyama P. S.

K_s, K_w: constants

Q_k: calculated value for mountain stream flow

Q': corrected flow quantity

Q_{0s}, Q_{0w}: turbine no-load flow rates

Equations (4) and (5) are the basic equations for satisfying the P_0 commands and for distribution computation to keep the regulating basin water level constant. The constants K_s and K_w are the ratios of output power to input flow for each power station. *Fig. 8* shows these *P–Q* curves. The characteristics of the Shin-Nakachiyama power station are very different from those of the Wadagawa No. 2 power station. This is because of the difference in the types of turbines and also because there is almost no changes in the effective loads since the regulating basin is operated at a controlled water level by this system. Therefore, only K_w is a variable constant to the computer.

An outline of the equipment for both power stations is given in *Table 1*. Therefore, the distribution calculation results are normally corrected within the limits indicated.

5. ΔP Distribution Calculations

The calculation equation for the ΔP (fringe component) distribution given as a whole from the CDO is as follows:

$$\left.\begin{aligned} \Delta P_s &= \frac{PS_{\max}}{PS_{\max}+PW_{\max}}\Delta P \\ \Delta P_w &= \frac{PW_{\max}}{PS_{\max}+PW_{\max}}\Delta P \end{aligned}\right\}\cdots\cdots\cdots\cdots\cdots(6)$$

where ΔP: $-70\,\text{MW} \leqq \Delta P \leqq +70\,\text{MW}$

$PW_{\max}$: max. possibie output of Wada No. 2

$PS_{\max}$: max. possible output of Shin-Nakachiyama P. S.

ΔP_w: ΔP value distributed to Wada No. 2 P. S.

ΔP_s: ΔP value distributed to Shin-Nakachiyama P. S.

Equation (6) indicates a proportional distribution of the ΔP command value in accordance with the generator capability. The result is a corrected calculation so that the sum of the P_0 distribution values (P_s and P_w) is normally within the generator capacities. It also takes into consideration the power

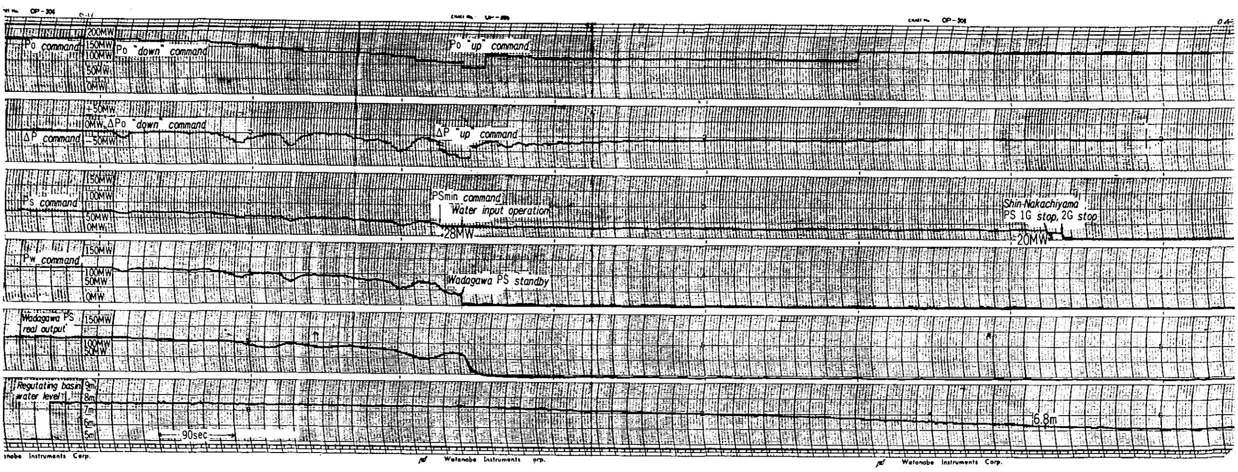


Fig. 9 Oscillogram of actual test

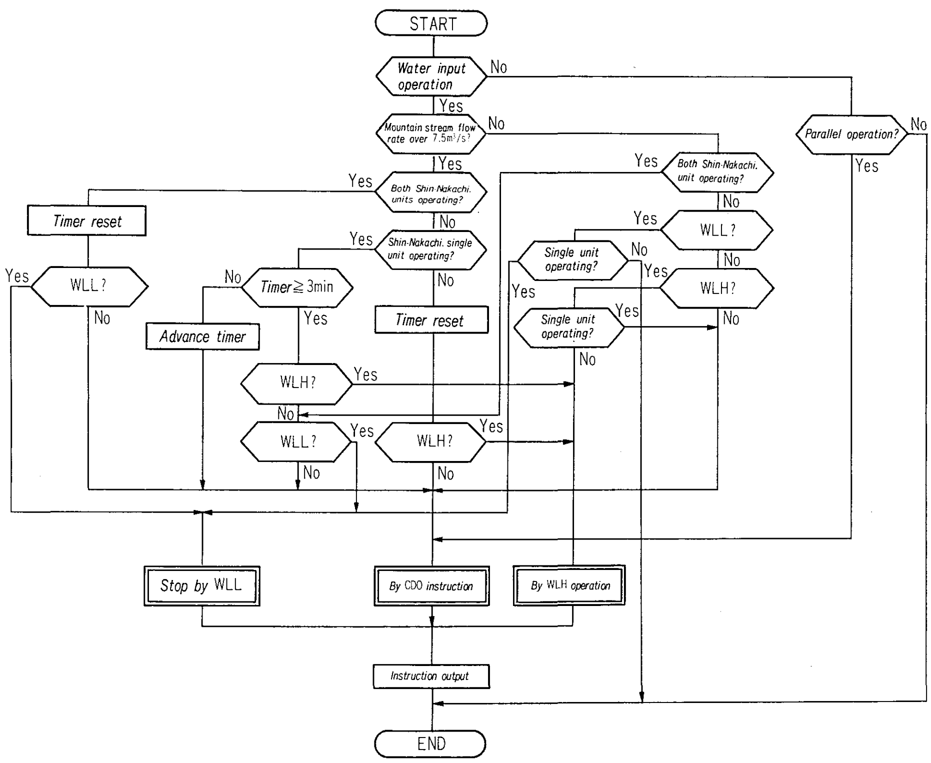


Fig. 10 Flow chart of water input operation

reservation between the generators. The results of an actual test are shown in *Fig. 9*.

6. Water Input Operation

Fig. 10 shows an outline of the water input operation. Water input operation is in accordance with the calculated value of mountain stream flow and is divided into the following operation modes.

1) Mountain stream flow is less than set valve
(1) There is automatic starting and stopping at the operation upper and lower water level limits.
(2) When one unit is operating, the second unit is started by a starting command from the CDO but the two units are both stopped at the lower limit of the water level.
(3) The output command values during operation are follows:
(a) one unit in operation: 20 MW
(b) two units in operation: 28 MW
(4) There is no AFC response
2) Mountain stream flow is over set value
(1) There is constant level operation in accordance with standard operation water level.
(2) AFC response is only ΔP (fringe component).
(3) If the upper or lower limit of generator output is achieved during operation and the water level reaches the upper or lower operating limit, the second generator is automatically started or stopped.
3) Starting and stopping from operator's console in CDO
(1) When one unit is in operation, it can be stopped

by a stop operation from the CDO but if the upper operation water level limit is reached, one unit is automatically stopped in accordance with the priority sequence set in the computer.

If a starting command is given to the other unit from the CDO during operation of one unit, this unit is started but when the calculated value of the mountain stream flow falls below the set value during operation of the two units, both units are stopped automatically at the lower operation water level limit.

(2) During complete stoppage, starting occurs in accordance with commands from the CDO but there is automatic stopping at the lower operation water level limit.

The results of an actual test are shown in *Fig. 9*.