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CENTRALIZED CONTROL SYSTEM OF HYDRO ELECTRIC POWER STATIONS OF THE KINUGAWA RIVER, THE TOKYO ELECTRIC POWER CO., INC.

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I. FORWARD

Formerly, remote supervisory control of the hydroelectric power stations of the Kinugawa River system was performed by a 1 : 1 telecon system. However, an electronic computer has now been introduced into the system to modernize the facilities and increase operating efficiency.

This system plan was started in 1976 and, after a year of design and manufacture, operation was initiated in April 1977. The supervisory control objectives are 7 power stations, 1 reservoir, and 5 regulating ponds. The system does not stop at supervisory control of each of these individual objectives, as in the past, but also features overall network system operation control and water system operation control.

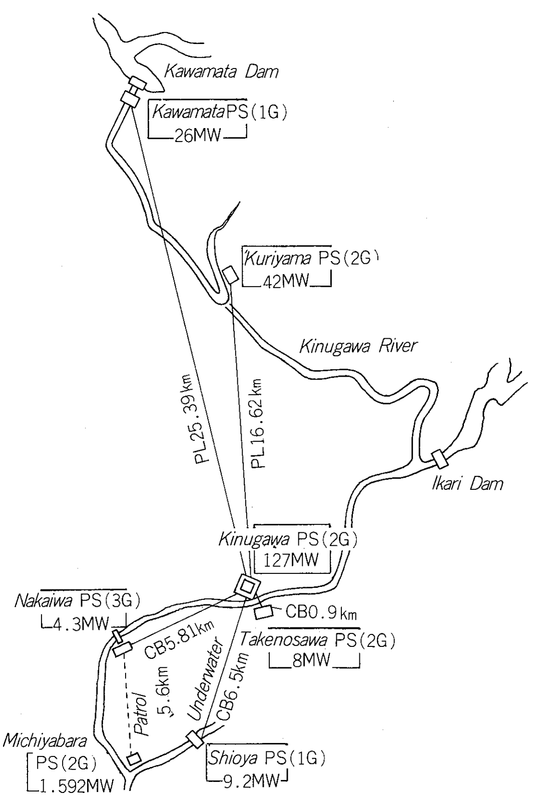


Fig. 1 Geopgraphical location of the Kinugawa river

II. OUTLINE OF SYSTEM FUNCTIONS AND CONFIGURATION

1. Functions

This section outlines the functions that will be described in detail in Section **III**.

1) Control

(1) ON/OFF control (CRT and back up control desk) of each electric station equipment (CB, LS, etc.).

(2) Numerical control (CRT and back up control desk) of each electric station equipment. (generators and Gates)

(3) Automatic network operation in normal condition (CRT).

(4) Automatic network operation in fault condition (CRT).

(5) Optimum water system operation (CRT).

2) Display and recording

(1) Display of each electric station equipment status fault (CRT and power system panel and water system panel).

(2) Automatic recording of each electric station equipment operation and faults (SF print).

(3) Recording of each electric station operation (daily, monthly reports).

(4) CRT hard copy

2. Configuration

This system consists of a single computer system (however, the CRT is redundant) backed up by back up control desk-telecon control and power system panel and water system panel display. *Fig. 2* is the system block diagram. The following outlines the main hardware.

1) CPU: 1
PFU-300
Core memory capacity 64 kB

2) Desk: 1
PF-6036 A
Memory capacity 1024 kB

3) Process I/O controller: 1
RTC
CDP (telecon input) 1 channel (for 5 stations)
SVI (local telecon input) 1 channel
ILO (telecon output) 4 channels
DI (digital input) 6 words
DO (digital output) 14 words

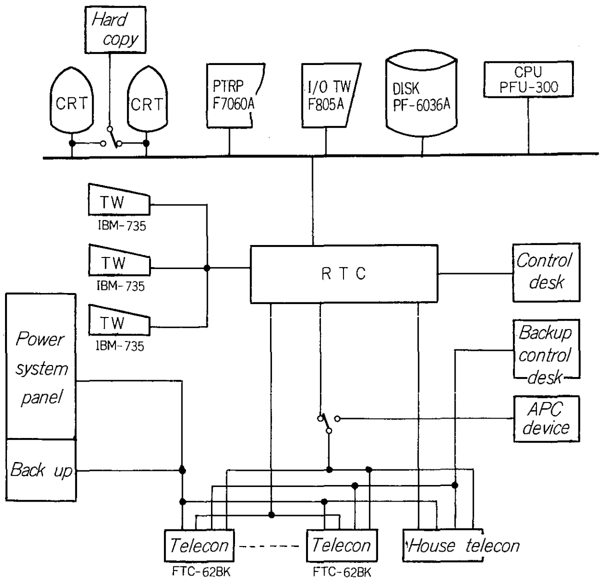


Fig. 2 System block diagram

AI (analog input) 20 channels
IOC (I/O controller) 3 channels

4) I/O typewriter: 1
F805A
5) SF typewriter, daily/monthly report typewriter: 3
IBM735
6) Paper tape reader/punch: 1
PF-7060A
7) CRT (with light pen): 1
Maximum characters: 4000 (100 chars x 40 lines)
Character set 128
Colors 7
8) Hard copy device: 1
Recording size B5
Color Black/white
Continuous recording 1 ~ 19 pages
9) Telecon: 4 sets
FTC-62BK
ON/OFF control Max 80 positions
Numerical control Max 3 quantities
SV display Max 200 positions
Telemeter Max 32 quantities (including subcommutation)
Computer I/O 1 set

III. FEATURES OF HARDWARE

1. CTC

1) CDP device

Telecon-CPU data interface is usually word series, bit parallel DMA, and status changes are detected by the CPU. However, in this new system, a device called a CDP (Cyclic Digital Processor) is inserted between the telecon and CPU. Status changes are detected inside the CDP, but only the status change data are DMA interfaced with the CPU. This system substantially reduces the program occupancy rate of the telecon in the CPU.

2) DI-F + SVI device

Supervision control of the Kinugawa control station itself is also an objective of this system. This supervisory control also handles the largest amount of data. Viewing the system from the computer side, telecon is also applied to the Kinugawa station and the station is interfaced to the CPU in the same way as the other electric stations (i.e., previously described CDP interface). However, installing the telecon in the same compound is uneconomical, because the interfacing with the computer must be all bit parallel. The DI-F + SVI device was developed to overcome these contradictions. This method converts the all bit parallel inputs to word series bit parallel input similar to the telecon. The CDP method and DI-F + SVI method are shown in *Fig. 3*.

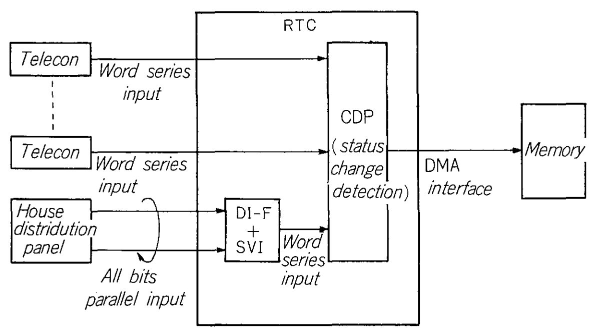


Fig. 3 CDP method and DI-F + SVI method

3) Back up system

As previously mentioned, this system is a single computer system. However, the following approach has been taken with the back up system.

(1) Telecon

Besides computer input, the telecon system contains I/O interface to a back up control desk, existing APC controller (other manufacturer), and power system panel. When a fault occurs at the computer, ON/OFF control and numerical control from the back up control desk, and numerical control from the APC controller are possible. Power system panel and water system panel display raises the telecon SV and telemeter output directly and is unrelated to the computer.

(2) Back up control desk (*Fig. 4*)

Basically, the back up control desk is a 1 : 1 telecon control panel that controls the system when trouble occurs at the computer. However, since housing all the control and display items at the back up control desk is difficult because of space considerations, the minimum number of control and display items are provided at a single desk of the same style as the operator console.

(3) Harmonizing with existing APC controller (other manufacturer)

Batch APC commands are transmitted from the central

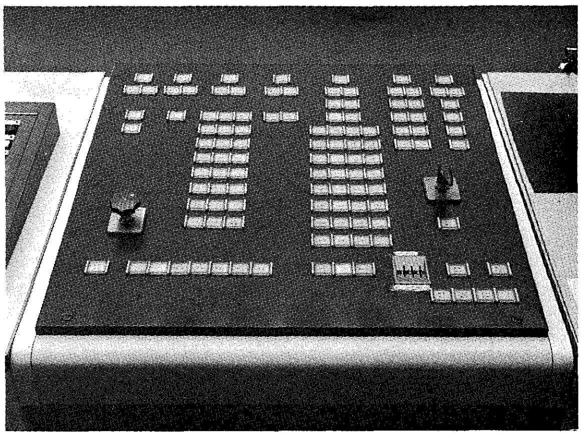


Fig. 4 Back up control desk

load dispatching station to the main power stations of the Kinugawa River system. The computer expands these commands by adding other conditions and sends the output command to each power station. On the other hand, an APC controller with similar function was already installed at the Kinugawa River control station. This existing controller is used as a back up device at computer shutdown. The computer and the existing APC controller normally perform APC operations in parallel and if trouble should occurs at the computer, the system is switched to the back up side by 43-APC switch operation.

IV. SYSTEM FUNCTIONS

This system utilizes the CRT and light pen functions fully and features excellent flexibility unaffected by functional restrictions imposed by the configuration of the control desk. The power station skeleton diagram, regulating pond water level curve, and daily and monthly report data can be displayed on the CRT by pushing the SCREEN SELECT, DISPLAY SELECT, DAILY/MONTHLY REPORT buttons. Pushing the SCREEN SELECT button displays the power station and network system skeleton diagram table, and pushing the DAILY/MONTHLY REPORT button displays the daily and monthly report table. A menu method that displays the desired screen on the CRT by selecting the desired item with a light pen is employed. Consequently, the number of CRT screens is not governed by the number of control desk pushbuttons and screens can be freely added and deleted.

This system has the following four main functions. The individual functions will be outlined later.

1) Supervisory control
2) Water system operation
3) Automatic NET WORK operation
4) Automatic recording

1. Supervisory control

The SCREEN SELECT button is a top and bottom lighted type. Pushing this button lights the bottom lamp and displays the preregistered skeleton menu. The top lamp indicates supervised power station and power transmission line fault or trouble, abnormal states. Flickering of this lamp indicates fault generation and resetting, and continuous illumination indicates continuation of the fault. The point at which the fault was generated, or is continuing, is indicated by steady red illumination or red flickering of the menu of the pertinent power station by pushing this button. The individual fault contents is displayed on the screen when the menu is displayed by selecting that point with a light pen.

The various equipment can be operated by pushing the SCREEN SELECT button to display the skeleton screen of the power station to be operated, then selecting the symbol of the desired equipment with the light pen.

Supervisory control of the power station and power transmission line is possible by merely pushing the SCREEN SELECT button and operating the light pen as described above. Since the equipment symbol on the skeleton screen can be directly selected with the light pen, there is no danger of erroneous operation and safety and operability are excellent. *Fig. 6* is an outline of the manual operation flow diagram using CRT.

2. Water-system operation

System configurations of the power stations of the Kinugawa river and Ojikagawa river are illustrated in *Fig. 7*. These power stations are mainly aimed at water supply (at flow rate at Sanuki) during irrigation period between the mid-April and mid-August and effective use of water in the other non-irrigation period. This system reduces the load on the operations and performs supervisory control of the power stations economically, quickly, and effectively by grasping the water level and torrent of each regulating pond and consistently operating the water system from operation scheduling to actual operation throughout the irrigation

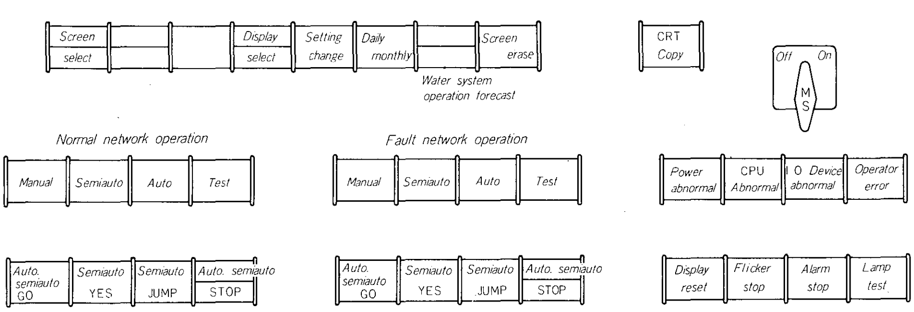


Fig. 5 Selective switches layout of control desk

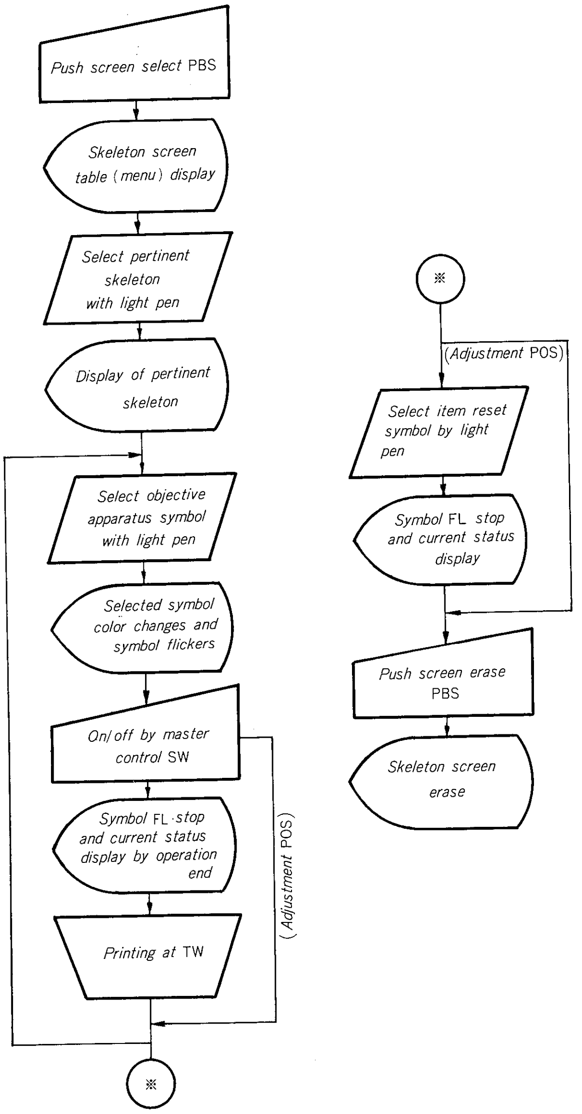


Fig. 6 Outline of manual operation flow diagram using CRT

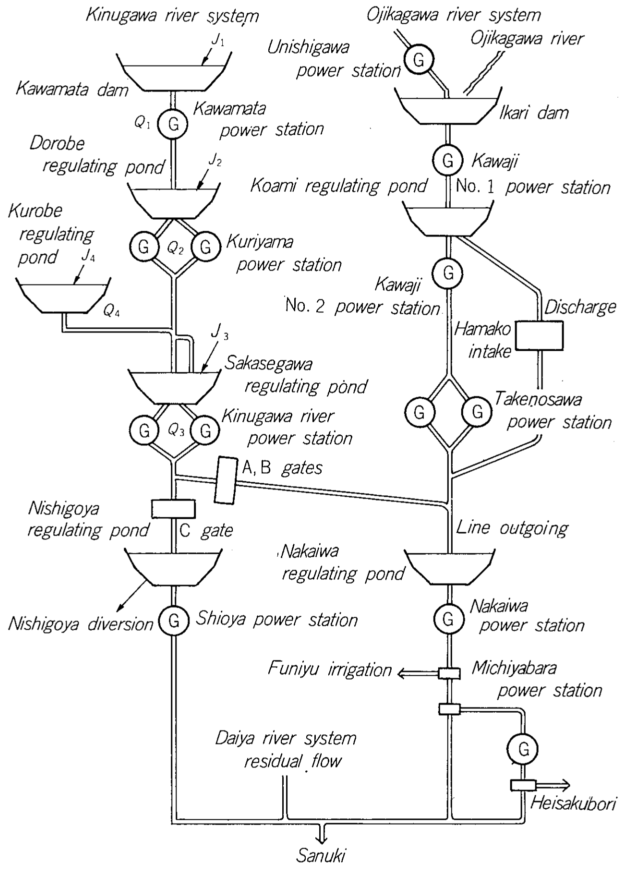


Fig. 7 Operation diagrams of the Kinugawa River and Ojikawa River

season and nonirrigation season.

During the nonirrigation period, in particular, the system prepares the next day's operation schedule forcast from the river flow for the Kawamata, Kuriyama, and Kinugawa rivers power stations and registers the forecasts as allowable power generation amount at the central load dispatching station. This schedule is made the standard and the distribution value varying from time to time, including the fringe amount, for the current day is received as output commands from the central load dispatching station and redistributed to each power station by APC.

The following introduces operating schedule preparation and actual operation of the above three power stations.

1) Operating schedule preparation

The water level and torrent of each regulating pond is reported to the central load dispatching station at 6:00 AM, the demand, economy, and Kawamata Dam operation plan are taken into consideration at the central load dispatching station and the power generation time frame and generated power of the Kinugawa River power stations are transmitted to the Kinugawa automatic control station. The operating time frame of the Kuriyama and Kawamata power stations is made the same as the operating time frame of the Kinugawa power stations based on the Kinugawa power stations operating schedule. The Kuriyama and Kawamata power stations operating schedule is computed so that the amount of water used by both power stations and the amount of water taken from the Kurobe rugulating pond are effectively handled under the following conditions:

$$\Sigma Q_1 = \Sigma Q_3 - \Sigma(J_2 + J_3 + J_4)$$
$$\Sigma Q_2 = \Sigma Q_1 + \Sigma J_2$$
$$\Sigma Q_4 = \Sigma J_4$$

Where,

Q_1 : Quantity used by Kawamata power station
Q_2 : Quantity used by Kuriyama power station
Q_3 : Quantity used by Kinugawa River power station
Q_4 : Quantity taken from Kurobe regulating pond
J_2 : Torrent to Dorobe regulating pond
J_3 : Torrent to Sakasegawa regulating pond
J_4 : Turrent to Kurobe regulating pond

This value is sent to the central load dispatching station as the next day's schedule. The operating schedule is prepared by a function that prepares the next day's schedule and current days' schedule to correspond to substantial changes in the flow due to torrent miscalculation and rainfall and the water level curves of each regulating pond for display on the CRT.

2) Operation

The current day's operation grasps the overall power demand from the central load dispatching station and distributes the APC command value transmitted via CDT to each power station. Distribution of the command values is based on the operating schedule values that handle the water level of each regulating pool as forecast.

(load distribution to power station A) = a x (APC command value) + b

$$a = \frac{\text{(Power station A maximum generating power)} - \text{(Power station A operating forecast power generating value)}}{\text{(Maximum total power generating value)} - \text{(Operating forecast power generating power value)}}$$

$$b = \text{(Power station A maximum power generating value)} - a \times \text{(maximum total power generating value)}$$

The deviation between the operating schedule value and central load dispatching station demand output and natural variations in the torrent are compensated by taking the AND with the regulating pond level changes without correcting at each. Flow compensation while corresponding to the APC command value is possible by checking the deviation between the forecast water level and actual water level every 10 minutes, and compensating for the deviation outside the allowable range by considering the changes in the torrent, etc. and making the correction based on the power/water ratio of each power station to shift the storage quantity of the Kawamata Dam.

(1) ΔQ compensation of Dorobe regulating pond storage quantity

$$\Delta Q_1 = -\frac{P_2 + P_3}{P_1 + P_2 + P_3} \times \Delta Q$$

$$\Delta Q_2 = \Delta Q - \Delta Q_1$$

$$\Delta Q_3 = \Delta Q_2$$

(2) ΔQ compensation of Sakasegawa regulating pond storage quantity

$$\Delta Q_1 = \frac{P_2 + P_3}{P_1 + P_2 + P_3} \times \Delta Q$$

$$\Delta Q_2 = -(\Delta Q - \Delta Q_1)$$

$$\Delta Q_3 = \Delta Q_2$$

Where,

ΔQ_1 : Correction quantity for Kawamata power station.
ΔQ_2 : Correction quantity for Kuriyama power station.
ΔQ_3 : Correction quantity for Kinugawa power station.
P_1 : Electricity – water ratio of Kawamata power station.
P_2 : Electricity – water ratio of Kuriyama power station
P_3 : Electricaly – water ratio of Kinugawa River power station.

As the final stage, if the actual water level is applied to the regulating pond limit water level, the downstream power station is switched to constant output operation and corresponded to the output command value from the central load dispatching station at the remaining power stations.

3. Automatic operation for network

Automatic operation under normal conditions and automatic resetting under fault conditions are the objectives of automatic operation. Power transmission line units use, halt, operation immediately after full stop, full stop resetting, and line fault resetting are possible. An automatic operation transmission line units skeleton screen, as well as a supervisory control skeleton screen, is provided so that not only the status of the system to be operated, but also the associated system data, can be positively grasped.

1) Operation under normal conditions.

Operation is initiated by selecting a specific symbol of

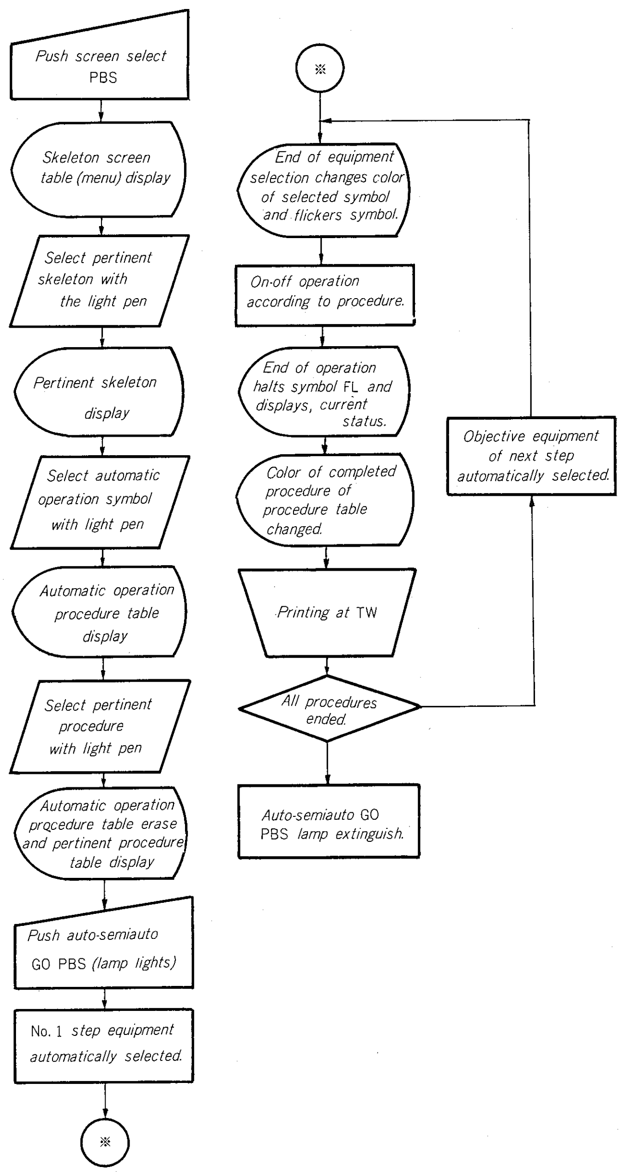


Fig. 8 Outline of automatic operation flow diagram in normal condition

the pertinent transmission line units skeleton screen to display the pertinent automatic operation menu, specifying the desired operation item with the light pen, and, after operating procedure is displayed, pushing the control desk GO button.

2) Automatic resetting at a fault

Operation is initiated by automatic association by trouble detection relay, etc. signal and resetting the system to the state prior to generation of the fault.

There are the following three operating modes:

(1) Semiautomatic

If the operaing conditions are satisfied, the equipment are automatically selected according to the procedure, and at the end of selection the operator checks if the equipment were selected correctly and pushes the YES button to output the control signal.

(2) Automatic

One string of related operations is performed automatically at fixed time intervals. The operating conditions are checked at equipment selection and control signal output.

(3) Test

The system status is reproduced inside the computer, without sending the control signals to the outside, processing is performed for each operation and the result is used to check the procedure, etc. When a trouble of network occurs during testing, the test is automatically halted.

Fig. 8 shows the procedure for automatic operation in normal condition.

4. Automatic recording

The automatic recording is subdivided in the following three modes:

1) Operation/trouble recording

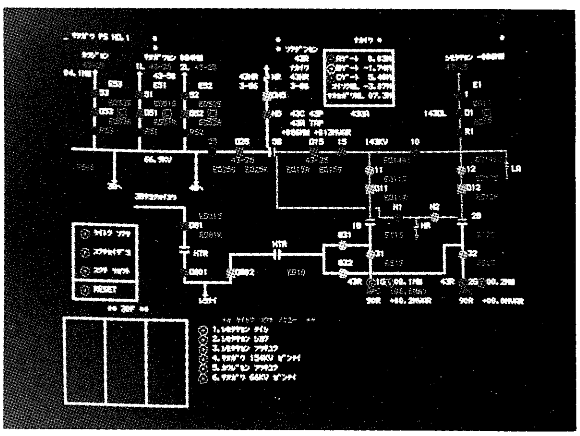
Troubles and resetting-switching occurring at the power stations are recorded by printing the time, station name, equipment name, and operating condition in black at a typewriter and printing the trouble related items in red.

2) Daily report

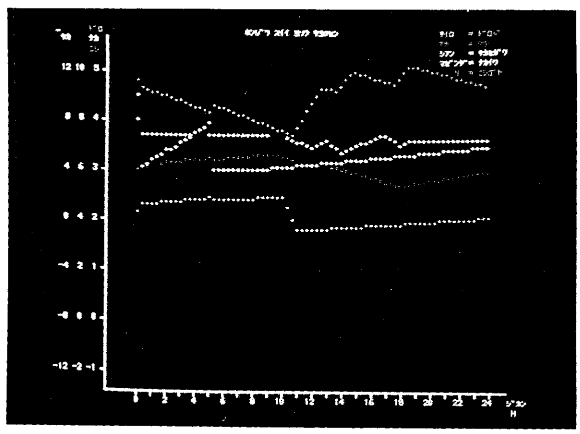
The generated power quantity, water quantity used, water quantity unused, regulating pool water level and other instantaneous valves and accumulated values are printed for each power station at fixed times (0, 3, 9, 12, 14, 18, 24 hours).

3) Monthly report

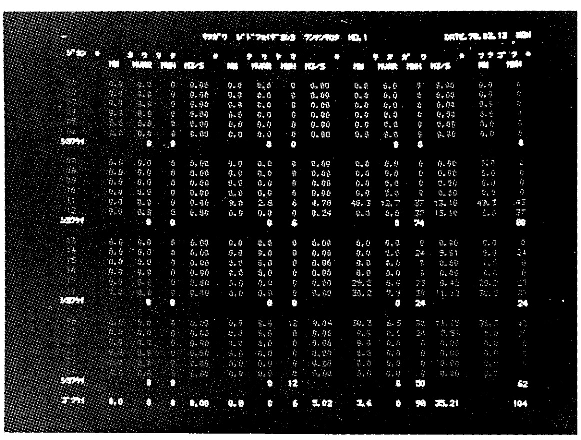
There is a monthly power station output report (7 pages), monthly Kawamata reservoir report, monthly substation main items report (2 pages), and monthly water temperature control report. These reports can be printed by request from the CRT. The monthly operation and maintenance management report is provided to prevent trouble in advance, quick detection of troubles, and for more efficient partrolling. The hydraulic turbine generator oper-



(a) Line diagram



(b) Water level forecast curves



(c) Operation management monthly report

Fig. 9 CRT display

ating time and the operating times and speed of various pumps, and the operating speed of CB, etc. are integrated and printed.

The daily and monthly reports data can be displayed on the CRT and recorded by hard copy as required. Therefore, the number of typewriters is held to 3 (SF printing, daily report, and monthly report) by referring to the items printed at the typewriter at the CRT screen and mutual back up when trouble occurs.

V. CONCLUSION

The authors wish to express their appreciation to all those who assisted in the design, manufacture, testing, and construction of the system introduced above, and will be happy if this experience contributes to the development of centralized control of hydroelectric systems in the future.