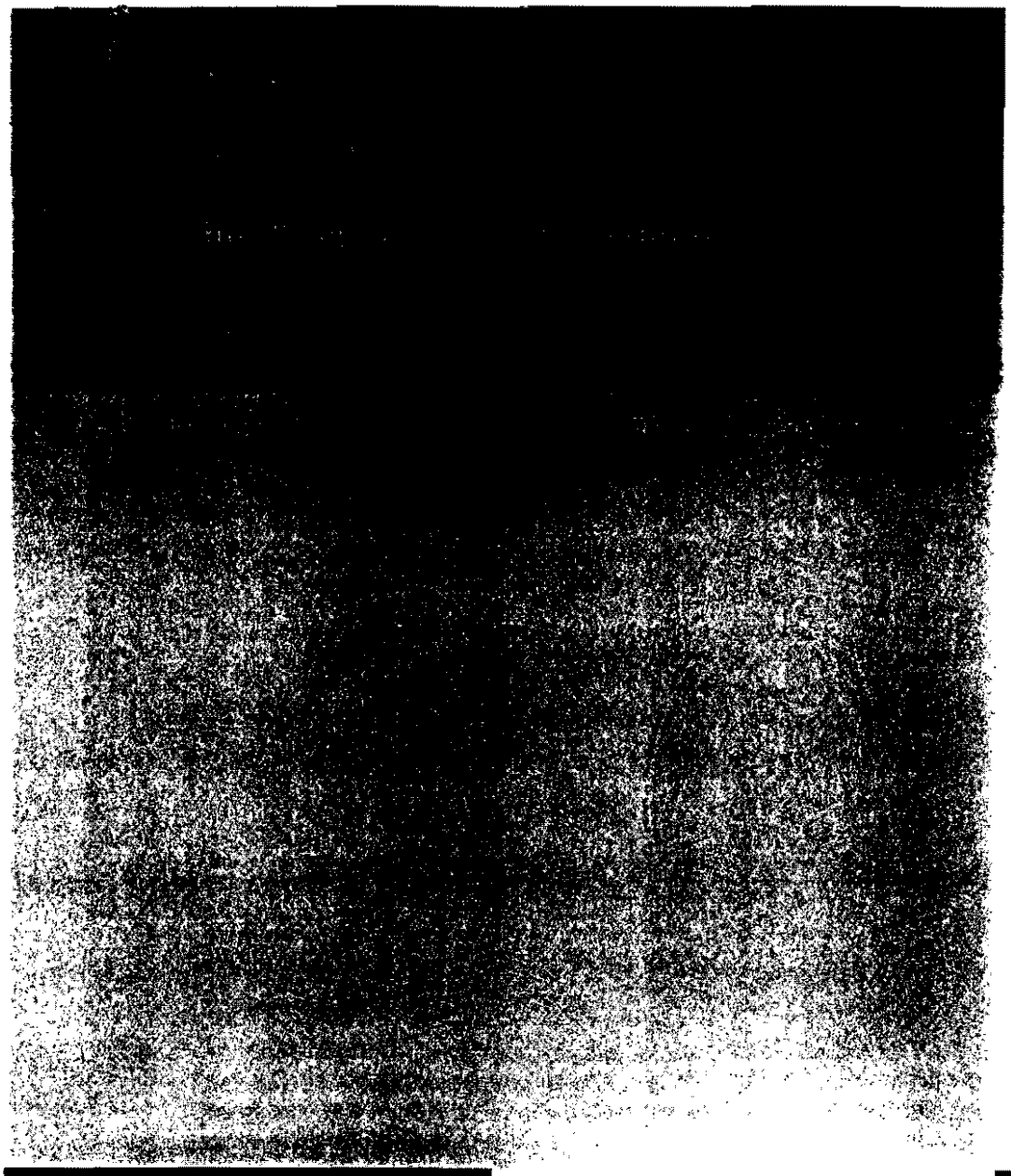
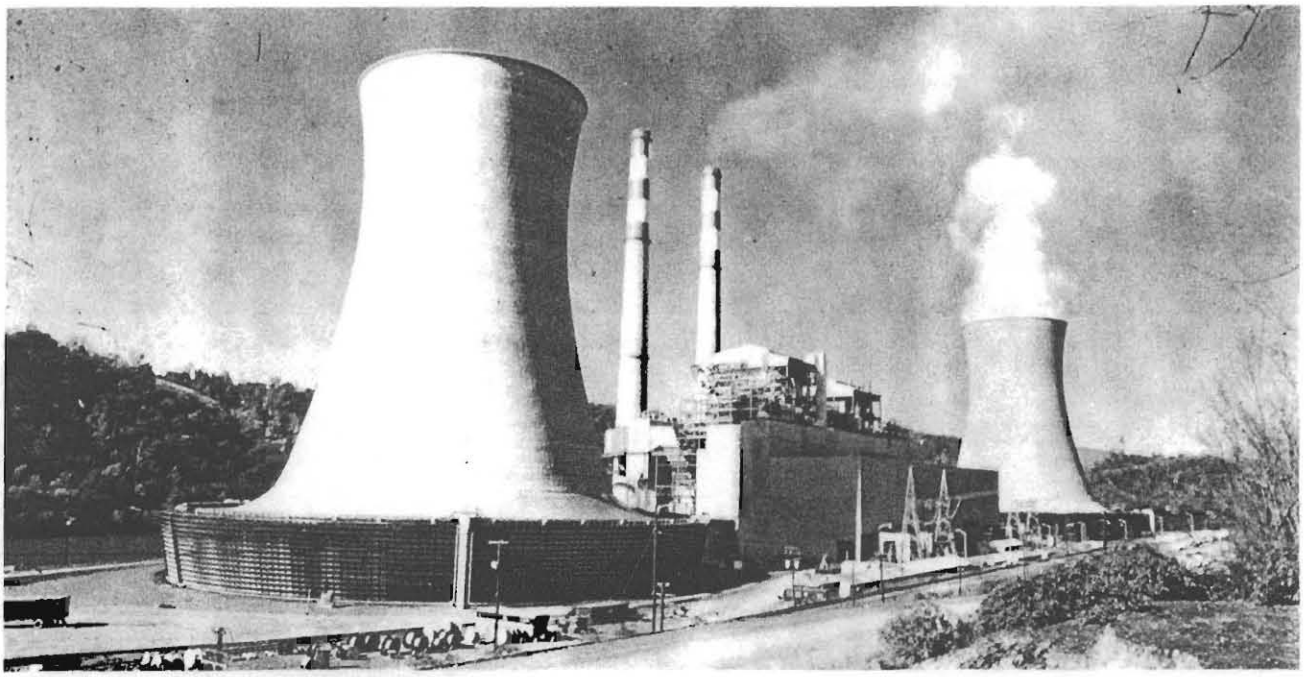


IBM

Application Brief



Allegheny Power System's Fort Martin Station located near Morgantown, West Virginia has a generating capacity of 1100 megawatts.

ALLEGHENY POWER SYSTEM serves about 885,000 customers in a 29,500 square mile area consisting of parts of Pennsylvania, Ohio, West Virginia, and Maryland. In 1967 the three major market revenue areas were divided according to the following proportions: residential, 41.4%; commercial, 17.5%; and industrial, 37.6%. The system includes 13 steam power stations and one major hydroelectric station with a total of 42 major generating units and a combined capacity of 3,400,000 kilowatts. The system comprises some 4,600 miles of transmission lines and 43,500 miles of distribution lines.

Economic Dispatch Control on the IBM 1800 for Allegheny Power System

INTRODUCTION

In 1964 Allegheny Power System determined that a major updating of power dispatching facilities was required to ensure the economic regulation of generating stations and the maintenance of scheduled power flows with non-affiliated utilities. A part of this program was construction of an extensive 500 KV transmission system. Since the analog computer and control equipment then installed at the System Operation Headquarters in Charleroi, Pennsylvania were designed to handle only a specific number of generating units and tie lines, it was necessary to plan for the installation of a new power dispatching computer.

After an extensive study, APS decided that the most economic and efficient installation would be a digital computer system that could perform load frequency control, economic dispatch, logging, alarming, and the additional functions appropriate to power dispatching. The new system should be compatible with existing communications and control equipment at the generating stations so that these facilities could be retained as backup for the system and the purchase of new equipment could be kept to a minimum.

The computer that met these requirements was the IBM 1800 Data Acquisition and Control System, which was placed in service to perform online control in December 1967.

Recently Mr. H. T. McCarthy, project coordinator at APS, stated, "Before we installed the 1800, our analog computer performed only economic dispatch with a single loss formula. With the 1800, we can now integrate and weigh additional steps in economy energy pricing; we can use a variety of loss formulas to achieve more accurate results and quote more accurate prices."

"We feel that an all digital system – such as the IBM 1800 – has a distinct advantage over an analog system: when additional tie lines or generating units are added to the network, the analog system requires more hardware; with the 1800, only program changes have to be made. As a result, the cost savings we realize are considerable."

ADVANTAGES

Among the specific improvements achieved at Allegheny Power since the 1800 became fully operative are:

Load Frequency Control. There is less overregulation: the system can be interrogated more efficiently, the readings are analyzed more rapidly, and adjustments are performed more accurately. Generator control impulses are more effective than formerly because the generating units are adjusted only when it is necessary to correct generation due to fluctuation of the load. With the computer's ability to coordinate impulses to minute tolerances, overshooting the limits of the system is no longer a major problem.

Economic Dispatch. The system can now calculate (1) the desired settings for all equipment operating under load frequency control and (2) manual or automatic settings for all equipment whether or not they operate under load control.

Alarming. The system now performs alarming for regulating errors that occur within specific rates or ranges (for instance, excessive tie line flows, excessive area control errors, and excessive frequency changes).

Trip-outs. In telemetering failures, tie line values are now automatically replaced with the previously recorded value; the continuous operation is performed without manual intervention. Previously, the equipment tripped out and manual entries had to be registered. When a remote station trips out, the system can now calculate the value of that station without affecting its operation.

Logging. The 1800 records and prints the status of individual units (net outputs, cost curve number used, response rates, load control limits, minimums and maximums), enabling the power control supervisor to operate the system more reliably.

Displays and Graphic Recorders. The dispatcher (Power Control Supervisor) can request, on demand, a console display of system load and generation, regulating ranges, and rates. The graphic recorders indicate, linearly, the total load and the area control error.

IBM 1800 DATA ACQUISITION AND CONTROL SYSTEM

The computer installation for Allegheny Power System includes the components and characteristics described below.

1801 Processor Controller—includes 32,768 words of core storage together with the logic and control functions for the system. A console is provided for programmer communication with the computer. The controller contains an analog-to-digital converter used in the telemetering operation and a comparator that performs automatic range checking on digital values developed by the converter.

1826 Data Adapter Unit—expands the digital input/output capabilities of the 1800 by accommodating up to 576 digital process termination points.

1816 Printer-Keyboard—is a combined keyboard and printer for manual input and system output; it operates at a maximum speed of 14.8 characters per second on a maximal 13-inch writing line. The 1816 is used to input certain values in the system.

1442 Card Read Punch—reads cards serially at the rate of 300 per minute and has a rated serial punching speed of 80 columns per second. The punch contains two card stackers and an automatic checking feature for all data punched. Format control and analysis are controlled by the 1801 processing unit.

1810 Disk Storage – uses two-surface disks that store up to 512,000 sixteen-bit words each. Instructions for the scan, economic dispatch, and load frequency control programs are stored on this unit, which reads from and writes on the disk at a rate of almost 36,000 words a second.

1053 Printer—has a stationary carriage and a maximal 13-inch-wide writing line. The unit is equipped with three keys to perform tabulation, spacing, and carrier-return functions. The reports and logs that are output from the 1800 system are prepared on one of the two 1053 Printers installed for Allegheny Power System.

In allocating power generation, the computer considers transmission losses, fuel costs, incremental heat rates, maintenance costs, and other factors. The 1800 also continuously monitors and records day-to-day operations of the system to produce the reports and graphic displays that help ensure an efficient and stable power supply throughout continuous fluctuations in demand and generation.

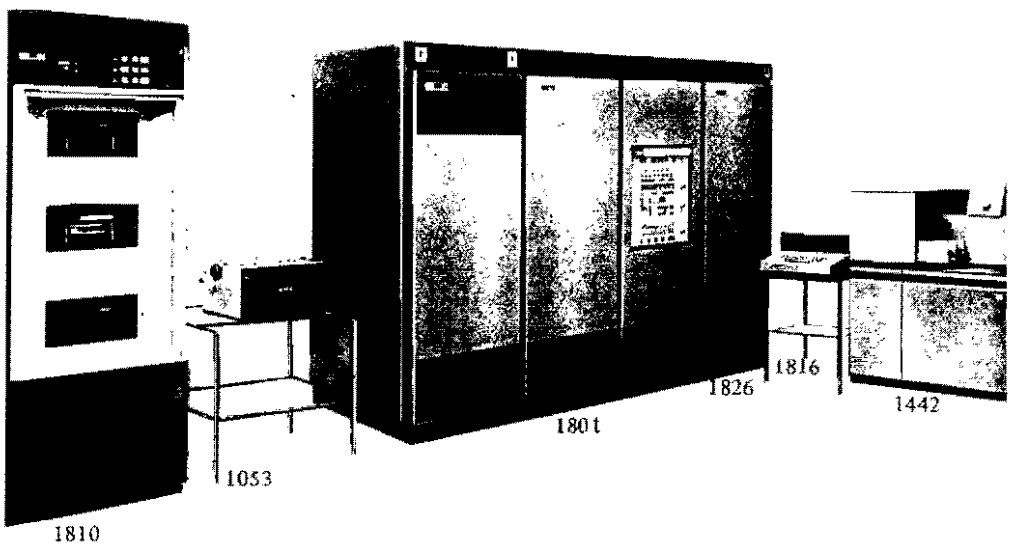
The economic dispatch control system automatically controls the output of 23 generating units in the five-state transmission area. The Allegheny Power System also monitors 17 tie line points (which are interconnections with five non-affiliated companies) in order to improve the reliability and economy of power throughout the service area.

INPUT

As shown in the illustration, input data consists of both analog and digital telemetered quantities; these quantities originate in both the tie line and generating unit points. Failure of any of the digital telemetering points is recorded in the system by a red alarm light and a typed message to alert the power dispatcher to the time of the alarm condition and the value of the point when the failure occurred.

Digital data telemetered in the system consists of megawatt readings from accumulators and megawatt, megavar, and voltage readings from transducers. After being converted to digital format at the point of reading, the impulses are transmitted over insulated static wires and used as direct input to the 1800.

Analog data consists of a transmitted tone proportional to the amount of generator output or tie line flow; it is conveyed over leased telephone wires, converted to a d-c millivolt signal, and used in two ways: (1) directly to drive the analog meters that provide graphic records of generator and tie line values, and (2) as direct input to the 1800.



Digital telemetering is normally controlled by its own separate scan facilities hardware, but can be controlled by the computer when and if such operation is required. The analog scanning procedure is directly controlled by the 1800.

It takes about 70 milliseconds to retrieve a digital reading, (all analog readings are scanned once every 2.0 seconds). When megawatt hour readings are being scanned (once every hour upon receipt of an external timing signal), all readings will be retrieved in approximately 3.5 seconds.

The card read punch is used to input certain control programs into the system; the printer-keyboard is also used as an input device to record selected values in the system.

INPUT/OUTPUT

The console (see inside back cover) is a specially designed input/output medium to allow the power control supervisor to communicate with the computing facility. It contains pushbuttons and indicator lights to record power system changes and alarming. It also enables the dispatcher to make inquiries concerning point values and conditions.

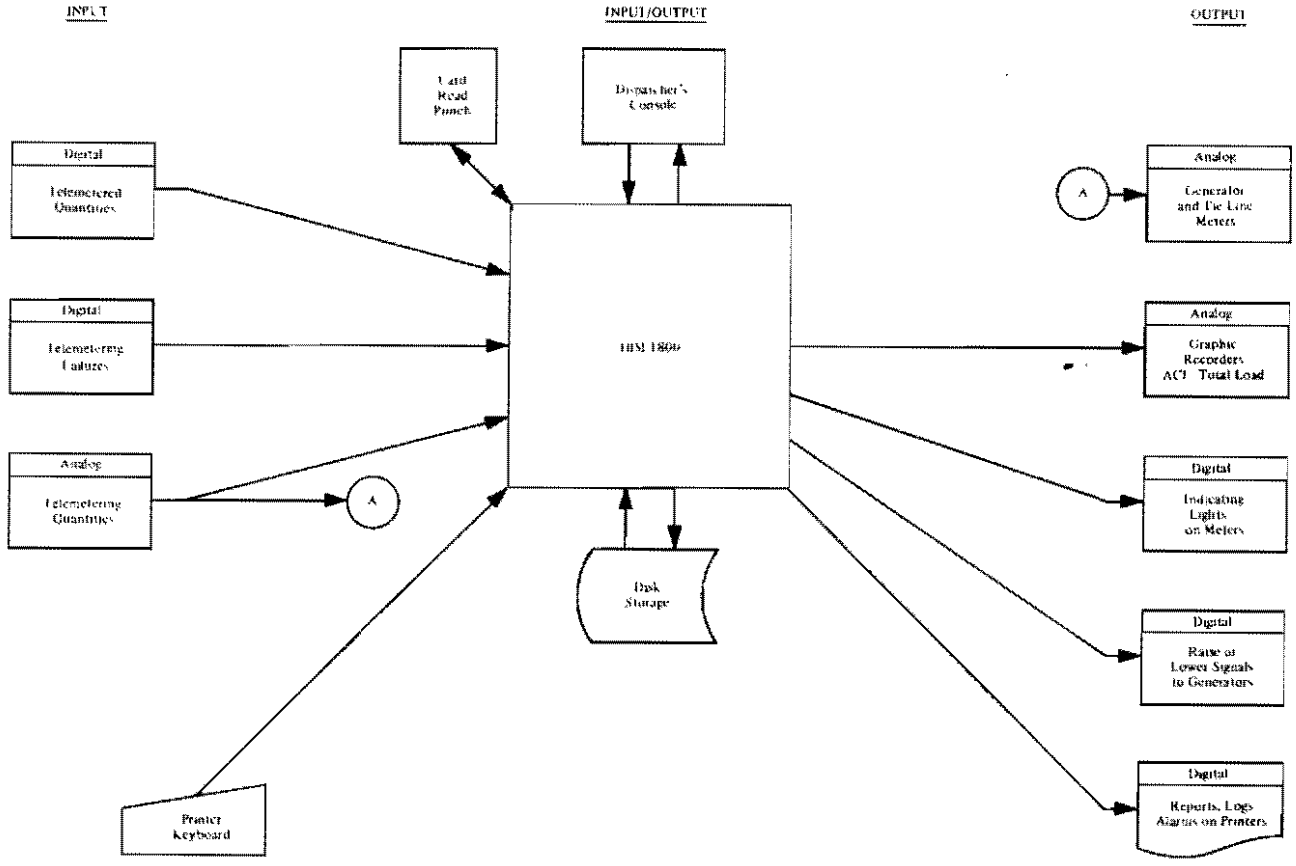
On the disk storage unit are recorded the programs that control the functioning of the system. These programs are instructions that direct the computer to perform particular functions in a specified sequence or order.

OUTPUT

All generator and tie line meters are driven by analog voltages. Those associated with analog telemetering points are driven directly by analog telemetered values, while those associated with digital telemetering points are driven by passing the digital data through a digital-to-analog converter. The 1800 illuminates an indicating light on each meter to designate either that (1) for a generator, it is on automatic load control, or (2) for a tie line, its telemetering channel is in service.

Other analog outputs are the graphs that record the area control error and the total load readings. After these values have been computed by the 1800, the resulting data is converted to analog voltages to drive the graphs.

Digital outputs consist of signals to raise or lower power from the system generators and signals to produce reports like economy energy pricing results, logs, and alarm messages. These printed records are run on the 1053 Printers.



SYSTEM CONFIGURATION

PROGRAM OPERATION AND CONTROL

The figure to the right illustrates the data flow through the system. The digital and analog input scan programs, the economic dispatch program, and the load frequency control program have been selected as examples of program utilization. Detailed discussions of the function and operation of the last two programs are found elsewhere in this brief.

The operation of, and displays on, the dispatcher's console, together with the logs, reports, and alarms produced on the 1053 Printers are also illustrated in individual sections of this publication. The strip chart meter outputs are graphic records of the area control error and total load.

Operations within the computer are controlled and regulated by the IBM Time Sharing Executive System (TSX), which allows the user to take advantage of the intervals during which the computer is not directly involved with controlling the power system to perform nonprocessing functions. The computed results of some of these functions are indicated in the printer outputs shown.

Within the processing – that is, the power controlling – function, the interrupt and associated control programs are handled by TSX according to a predetermined priority assignment. Prewritten analog and digital input and output programs, a job queue for scheduling low-priority programs, and many other features involved with process control programming are provided by the TSX system.

Over 150 programs make up the power dispatching area of responsibility for Allegheny Power System. This brief describes the following online and selective operating guidance programs available to the power dispatcher:

- Load frequency control
- Economic dispatch
- Economy pricing
- Logging
- Alarming
- Tie line flows
- Dispatcher communications and display

LOAD FREQUENCY CONTROL

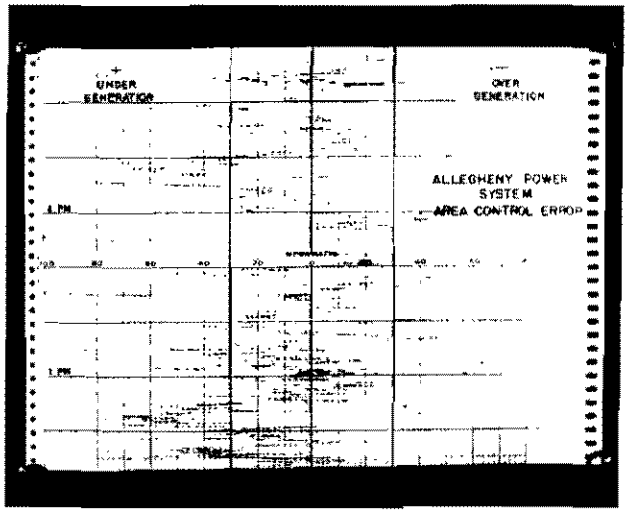
Allegheny Power System has 17 station combinations under load control consisting of 13 single-boiler turbine steam units, three steam header systems with 10 generating units, and one hydroelectric station with four units. The major functions encompassed by this program are:

- To calculate the area control error
- To calculate the unit corrections for automatically controlled generating units
- To adjust the generating units in conformity with their unit correction

A graphic record of the area control error (ACE) and the computer-smoothed area control error (SACE) are illustrated. The calculated ACE contains all of the instantaneous load swings (usually with a magnitude of 80 MW) that occur in the system. Since these swings fluctuate faster than the response of the regulating units, it is desirable to regulate on the load trend described by the ACE. The load trend is calculated as a smoothed ACE or SACE.

Load control depends upon the SACE magnitude:

1. Less than ±5 MW – no regulation



AREA CONTROL ERROR

ALARMING

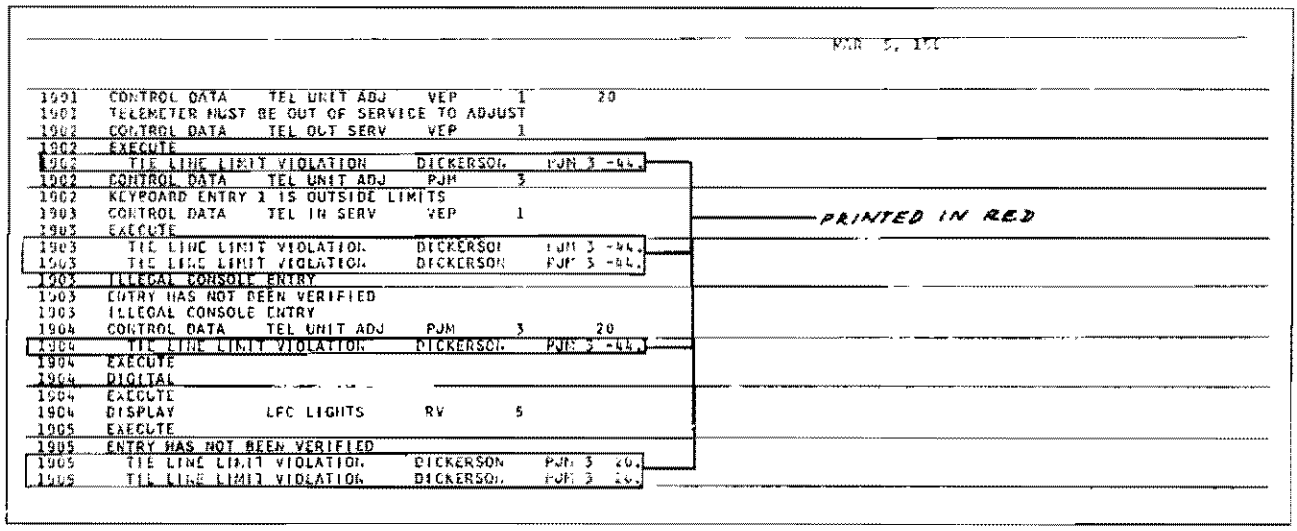
The following variables in the online programs already discussed are continuously monitored:

- Area control error
- Frequency
- Tie line limits
- Response rate
- Response range
- Telemetering failure

When any of these variables are out of limits, a gong sounds, a red alarm light describing the variable is lighted on the dispatcher's console, and a message is typed on the printer indicating the time of the alarm condition and the value of the variable at the time of violation.

The printout listed here shows power system alarm messages for a tie line limit violation. These alarm messages are printed in red; the data printed in black are verification and execution messages recorded as a result of action on the dispatcher's console. The console verify and execute procedure is explained in the section "Dispatcher Communication and Display".

The exact time of each message appears on the left side of the report.




```
1901  CONTROL DATA     TEL UNIT ADJ     VEP       1          20
1901  TELEMETER MUST BE OUT OF SERVICE TO ADJUST
1901  CONTROL DATA     TEL OUT SERV     VEP       1
1902  EXECUTE
1902    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3 -44.
1902  CONTROL DATA     TEL UNIT ADJ     PJM       3
1902  KEYBOARD ENTRY 1 IS OUTSIDE LIMITS
1903  CONTROL DATA     TEL IN SERV      VEP       1
1903  EXECUTE
1903    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3 -44.
1903    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3 -44.
1903  ILLEGAL CONSOLE ENTRY
1903  ENTRY HAS NOT BEEN VERIFIED
1903  ILLEGAL CONSOLE ENTRY
1904  CONTROL DATA     TEL UNIT ADJ     PJM       3          20
1904    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3 -44.
1904  EXECUTE
1904  DIGITAL
1904  EXECUTE
1904  DISPLAY          LFC LIGHTS       RV        5
1905  EXECUTE
1905  ENTRY HAS NOT BEEN VERIFIED
1905    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3  20.
1905    TIE LINE LIMIT VIOLATION        DICKERSON     PJM 3  20.
```

ALARM MESSAGES

TIE LINE FLOWS

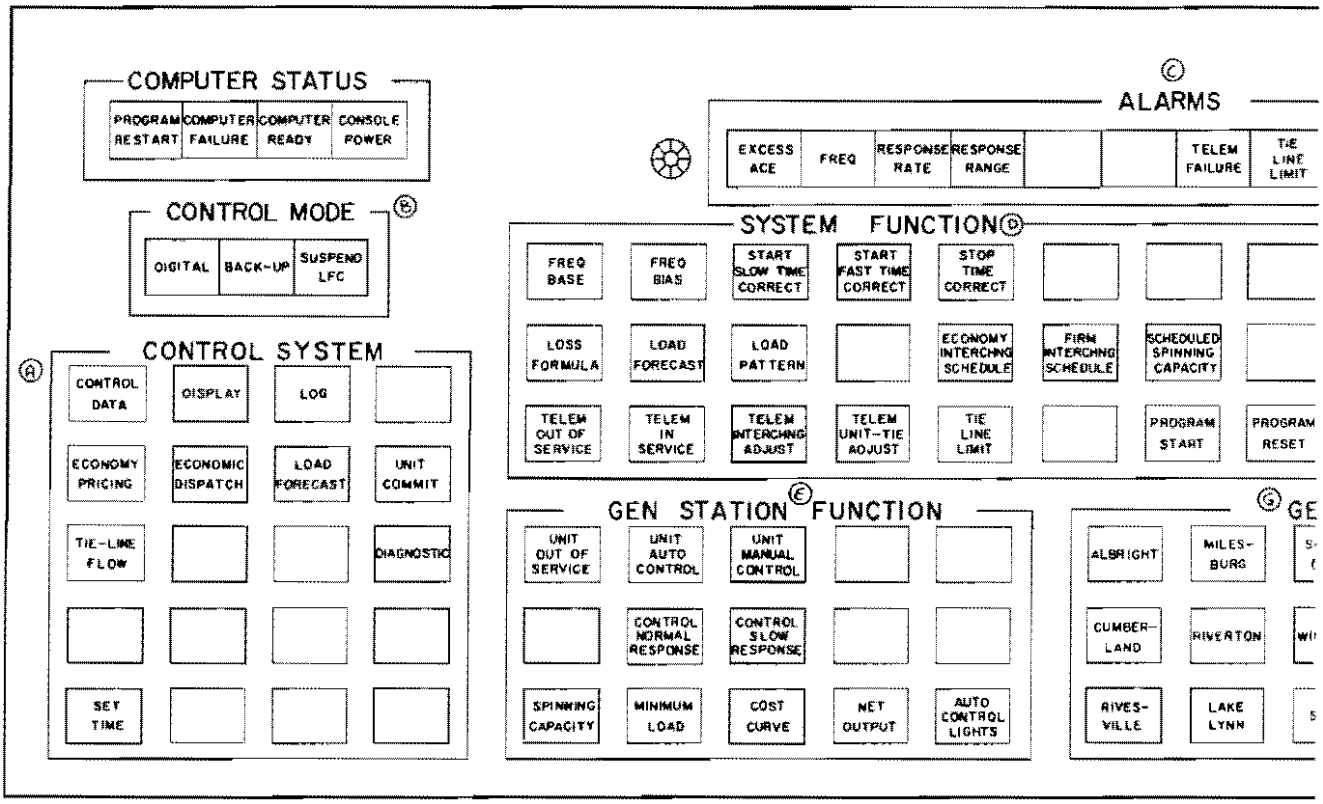
This is a study program that can be used by the dispatcher for determining tie line flows that would exist for any given set of schedules with non-affiliated companies.

The illustration tells how each of the tie line point MW flows (1) will be valued if an exchange occurs with the companies indicated (2) at the schedules provided (3). The current tie line limits for each point (4) are also recorded.

```
APS-AEP       SCHEDULE=  63.0MW
APS-DVEC(2)   SCHEDULE= 188.0MW(A)
APS-DE        SCHEDULE= 100.0MW
      TIE-LINE NAME          FLOW(MW)      T.L. LIMIT(MW)
         MATRIUM              (1) 10.          89.
         WINDSOR TIE             111.       (4) 228.
         WEIRTON                 173.          98.
         KAMMER                  -76.          500.
         WOLF CREEK               31.          199.
         BURMA                   -36.          248.
         BLAIRSVILLE              29.          134.
         DICKERSON               -81.          197.
         GARRETT                  11.           59.
         LINCOLN                 -18.          134.
         ROXBURY                  -2.          134.
         SHINGLETOWN              35.           74.
         KEYSTONE                -85.          650.
         RINGGOLD                  0.          500.
         ELKO TAP                  0.          500.
         CABOT                     0.          500.
         MITCHELL TIE           -140.          350.
         DOUBS                   270.          500.
         MT. STORM              -147.          600.
         WYLIE RIDGE               0.          500.
         ZELIENOPLE               37.          175.
         KEISTER                   0.          170.
```

TIE LINE FLOW PROGRAM

DISPATCHER COMMUNICATION AND DISPLAY



DISPATCHER'S CONSOLE

The dispatcher's console, shown above, is the means of communication between the power dispatcher and the 1800. The main *control system* program buttons (A) are located on the left side of the console and indicate which program mode is desired when an inquiry or entry is being made. The *control data* button is used for entering online data.

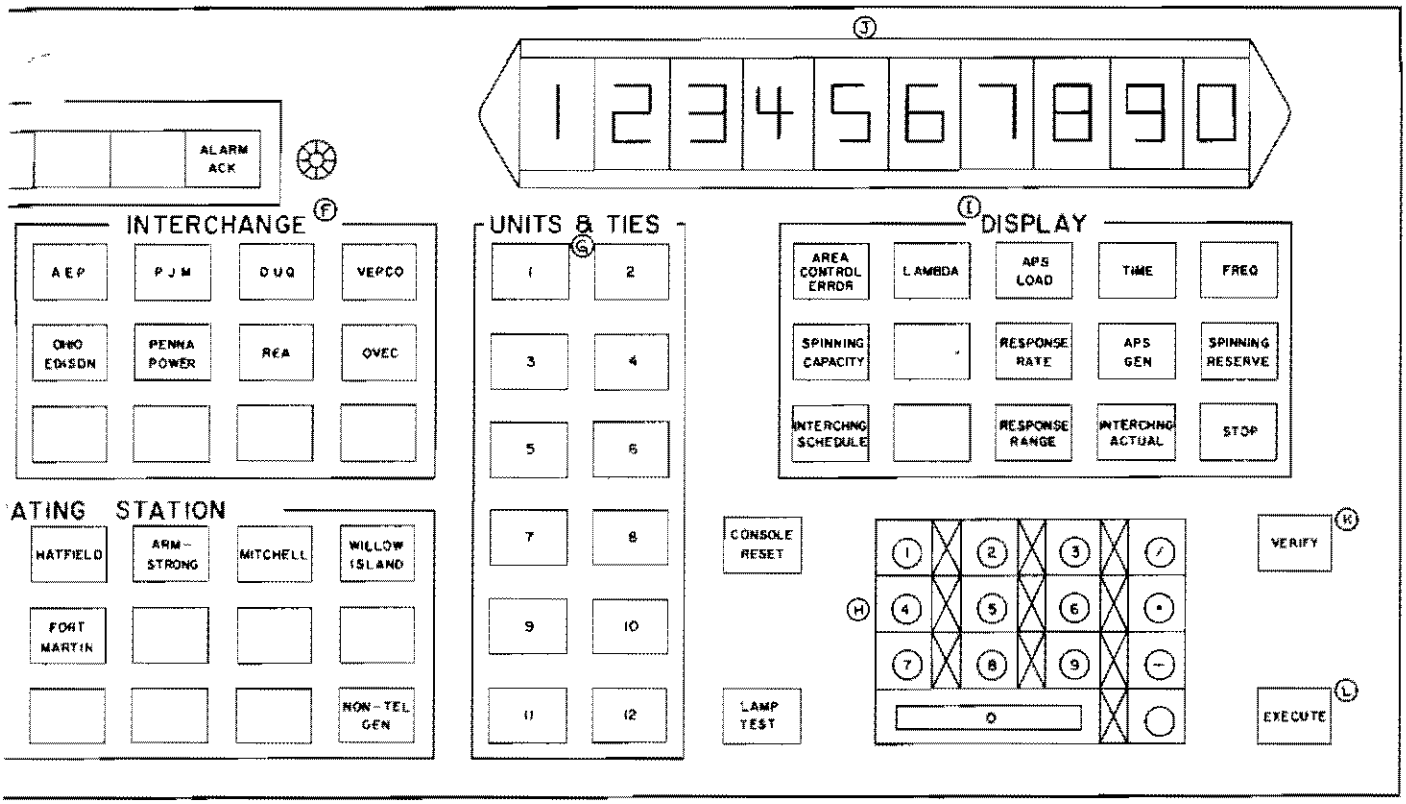
The two banks of lights labeled *computer status* and *control mode* (B) indicate specific operational conditions of the 1800. For instance, the *digital* light means the computer is controlling operations; the *backup* light means the analog backup system is operative; the *suspend LFC* light means that no impulses are currently being transmitted to the power stations.

The *alarms* lights (C) spell out specific alarm conditions that occur; the green and red lights -- on the left and right side of the alarms bank -- indicate that the generator whose impulses are being displayed is being lowered or raised, respectively.

The *system function* buttons (D) are used to make changes or additions to the values currently contained in each area indicated.

The *general station function* keys (E) are used when communicating with specific generating units or tie line points to indicate what functions are to be processed.

The *interchange* buttons (F) are used when making tie line transactions with the non-affiliated companies indicated.



The *generating station* and *units and ties* keys (G) are the names of the 14 stations and numbers of the 12 generating units within each station. They also indicate the tie locations in the interchange with non-affiliated companies.

The keyboard (H) allows entry, directly into the computer, of all digits, a negative sign, and a slash.

Through *display* buttons (I), the NIXIE* tubes (J), and a button operating sequence in the areas already discussed, the dispatcher can display unit net generation, tie line flow, or the impulses being sent to any selected generating unit.

*Registered trademark of the Burroughs Corporation.

The three programs that control all communications between the console and the computer are labeled "verify", "execute", and "keyboard". The last program handles the manual entries made on the keyboard as numeric input to the 1800.

The *verify* program (K) checks the previous data and control instructions that have been entered in the console. If all entries are valid, a full description of the button entries – together with the time of record – is printed on the 1053.

After keying and verifying the desired entries, the power dispatcher depresses the *execute* button (L) and the computer performs the necessary online changes and/or functions that have been requested.

FUTURE APPLICATIONS

The all-digital control system has been in service since the end of 1967. Ultimately, the system is designed so that all of the generating equipment operating under load control procedures will be placed under those procedures simultaneously.

Unit Commitment. Currently being developed, this program will tell Allegheny Power System which generating units should be operative – which units can be operated most economically for what period of time.

Load Forecast. An online program for future development, this program will provide better information for economy energy pricing to determine which equipment should be operative on what days.

Dispatcher's console, printers, and meters at Allegheny Power System's dispatch center, Charleroi, Pennsylvania.