Electrical World

On-line computer automates BPA system

BPA's Dittmer System Control Center nears completion, with data acquisition and communications network readied for integration

On-line computer automates BPA system

BPA's Dittmer System Control Center nears completion, with data acquisition and communications network readied for integration

When Bonneville Power Administration's $20-million William A. Dittmer System Control Center opens next year, at its center of operations will be a system known as Real-time Operations, Dispatch & Scheduling (RODS).

Dittmer Center's responsibilities will be to monitor and supervise more than 11,500 circuit miles of high-voltage transmission lines, to schedule and dispatch about 10,000 Mw from 26 federal hydroelectric plants, to wheel or exchange about 3,000 Mw for nonfederal utilities, and to confine trouble to the narrowest possible boundary with fast service restoration.

The $5.2-million RODS system, provided by TRW Industrial Operations Group, Redondo Beach, Calif., will receive information from a vast network of BPA stations and processes, and then store it for display and implementation in either "man-in-the-loop" or "closed-loop" controls.

"RODS will collect data automatically, run it on-line more times, and give us a chance to tune up our forecasting more times a day," says a BPA official.

RODS voltage schedule/control, an on-line optimal power-flow analysis, will provide a voltage profile on a systemwide basis. It will use manually input voltage constraints, and computed load injections and bus-load predictions, to tell the operator what voltage schedule would be best. It will also pass along the best setting for voltage-control equipment, using real-time data.

A network power-flow picture can be drawn up to one week ahead, using expected system loading and a variety of hypothesized conditions such as weather, hydromet, and generating patterns. This same network power flow will be computing bus load forecasts for both voltage schedule/control and the security monitor.

Generation and interchange scheduling for the system will require input on the power system, the weather, and hydrologic data. Out of that will come stream-flow and load forecasts, operations reports, and plant monitoring not only for the scheduling process but also for operations planning.

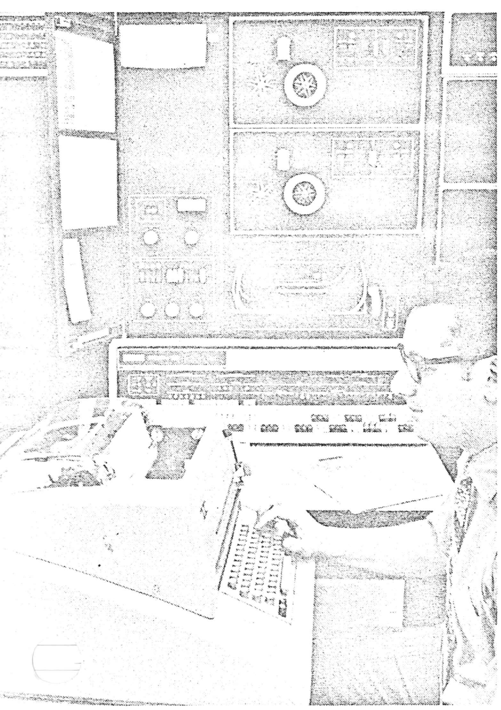
System security monitors will output the power-system status, both present and expected, and alert the dispatcher to unsatisfactory operating conditions that might reach a vulnerable stage, should certain contingencies occur. The system security monitor can hypothesize up to 200 contingencies, compute the corresponding power flows, and compare these with acceptable limits.

Although the various data received by RODS are expected to be accurate—power flow, bus voltages, supervisory control and data acquisition (Scada) input etc, will be checked frequently for error.

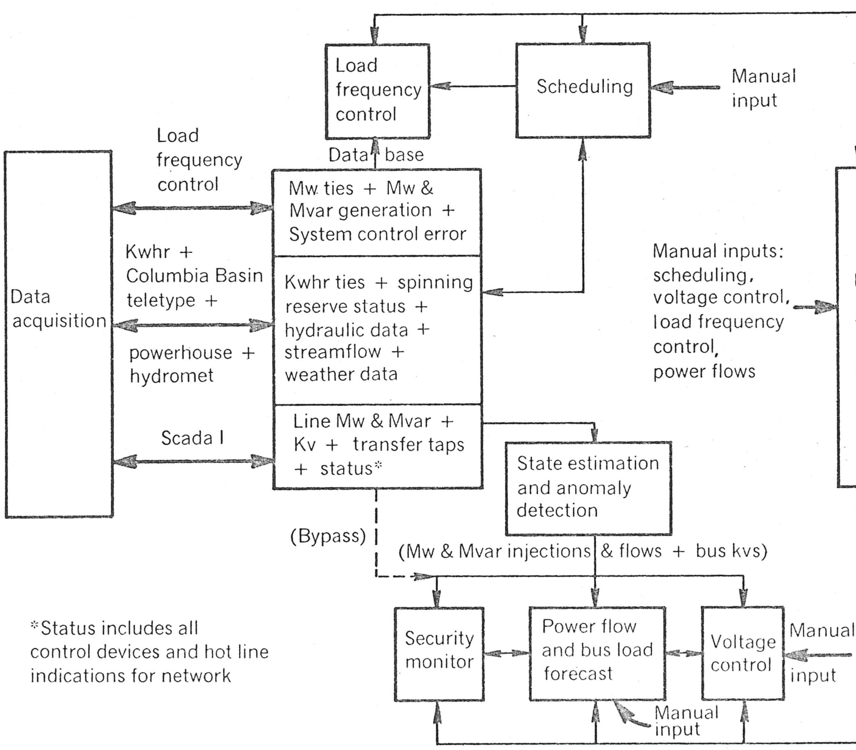
The system state estimator will combine measurements and pseudo-measurements with electrical admittances and probable error estimates to arrive at a "best fit" measurement which can be used instead of any questionable raw values. To detect anomalies, an algorithm checks the system state estimator and spots bad data points.

Redundancy a hallmark

Besides security, RODS design has focused hard on system reliability and availability. Redundancy, therefore, has been a hallmark.



Keyboard is linked with PDP-10 computer; hardware redundancy allows for failure



Only closed-loop function in software system is load frequency control

Reprinted from July 1, 1972 issue of Electrical World

Hardware configuration of RODS for normal operations is a primary system consisting of one Digital Equipment Corp PDP-10 and two PDP-11 minicomputers and their associated peripheral equipment. And all critical components on the primary system are duplicated on a secondary system.

In addition, should the primary PDP-10 fail, the complete system can be thrown over to the secondary system for continuing operations. This can be done in less than five minutes, with individual equipment switch-over accomplished in seconds.

The secondary system will not remain idle during normal operations. Without interrupting the primary's work, the secondary system computers can be used for on-line development of new programs or for modifying existing ones.

"New applications that will be spun out of the secondary-system development work will be development of more sophisticated methods of state estimation and systems security. They're just in their infancy in terms of potential," says Martin F. Kenehan, TRW's project engineer for RODS. "They're very complex and take a long time to run. Emphasis will be on speeding the process and obtaining more usable data."

Kenehan says other activities might be simulating power outages, or simulating new theories for scheduling.

Milton Brown, BPA project engineer, suggests that BPA will run expanded transient stability monitoring and control capabilities. "And we'll be simulating the primary system often to check out the system software before putting it on-line," says Brown.

Data-acquisition system

All data-acquisition points except one have RODS as master.

1. Scada I will be the prime source of main grid information for dispatch and scheduling. Data, updated every 3 seconds, will come from 45 remote main grid substations of 230 kv and over. Via a 40,800-baud binary synchronous data link, unscaled analog information like line loads, bus voltages, breaker status, and transformer tap settings will be transferred to RODS data processing in message lengths up to 3,000 bytes.

2. Load Frequency Control will feed analog telemetry readings continuously from 216 points, including interchanges and powerhouses. Input includes interchange megawatts, generation megawatts, and megavars. Output includes generation control errors computed for 15 stations (based on actual and scheduled interchanges with other utilities), actual and scheduled plant generations, and system frequency.

BPA officials say load-frequency control will be the highest-priority application performed by RODS, and it's the only closed-loop function where, in the event of an error signal, command is initiated automatically.

One primary function of RODS has been added since BPA conceptualization—a stand-alone capability for load-frequency control. "Even if both large computers fail, critical functions can be picked up by the minicomputer operating as backup," says Kenehan.

3. Energy flow from 92 remote interchange points, via a Varian 620/L, will be transmitted to RODS every 10 minutes in 512-byte blocks over a 2,400-baud, half-duplex link.

4. Powerhouse-status measurements, such as plant Mw and Mvar, unit status, alarms, spinning reserves, total Mwhr, bus voltage, frequency, forebay and tailrace water level, spill, and discharge—eventually will be transmitted to RODS over dedicated data links. Meanwhile, an interim system will feed RODS the status of generators at eight federal powerhouses via low-speed digital telemetry circuits. Telemetry receiver-decoders will be interrogated on a change of status or on demand.

5. Columbia Basin teletype, a multi-station private-line network operated by the Corps of Engineers, will exchange hourly plant scheduling and hydrometeorlogic information. RODS will be linked to 26 terminals along the network. This is the only data-acquisition point of which RODS is not the master.

6. Some 100 hydromet stations will feed RODS hydrologic and weather data via a 110-baud half-duplex communications line. About 1,400 bytes of information will be updated hourly.

7. The National Bureau of Standards station WWYB will provide standard time and frequency information to synchronize RODS software clocks to real-time power-system measurements within ±0.001 hz and deviation from standard time to 0.01 seconds.

Both BPA and TRW officials say RODS has encountered few difficulties. "We're now in between the development stage and the integration stage," says R.G. Gose, TRW Industrial Operations director of program development and management. "The moment of truth is still around the corner for us."

"I guess the big question mark comes after we integrate all the hardware and software and find out how they play together," says Kenehan, adding that total system integration is some months off.

TRW, which won the contract in May, 1971, must have installation completed early next year, with operation by mid-1973.

Subsystems

RODS consists of three subsystems; computers, data interface, and display.

Its computer subsystem receives, stores, and processes information from the network of remote stations. Then it feeds instructions back to them.

Hardware for the computer subsystem includes the two PDP-10s, each with a KA-10 central processor unit controlling data transfer between main memory and other computer subsystem components and performing arithmetic and logic operations. Each large computer has eight ME-10 memory modules with a total capacity of 128,000 words of interleaved core memory, and with a 1.0-microsecond cycle time.

The computers' auxiliary memory is in the form of the PR-10 disc-pack controller with two RP-02 drives providing 10,393,600 36-bit word storage, average access time of 62.5 milliseconds, and a transfer rate of 15 microseconds per word. Fixed-head discs are the RC-10 disc controllers with up to four RD-10 swapping disc files, each of which can store 512,000 36-bit words.

The large computers have magnetic-tape and hard-copy capabilities (card punch, card reader, line printer, and hard-copy controller). A stall alarm notifies operators when instructions are not carried out within 500 milliseconds.

The primary and secondary computer systems are linked with an IP-10 interprocessor buffer. Communications with the data-interface subsystem is via DA27C and DA27C-CF interface buffers configured to ensure maximum availability in various failover options.

Control center covers 118,200 sq ft. It will be used to monitor and supervise 11,500 transmission circuit miles, schedule and dispatch 10,000 Mw, and wheel or exchange 3,000 Mw

Data interface links the RODS computer subsystem will all real-time data-acquisition terminals.

The two PDP-11s in the primary (real-time) system control the data-interface functions and data transfers to the display subsystem. A third PDP-11 is the backup (secondary) and provides input to displays or data interfaces from off-line functions for the secondary PDP-10. It also stores the load frequency-control program, allowing this "highest priority" function to stand alone even if the two large RODS computers shut down.

The data-interface PDP-11 and the secondary PDP-11 have core memories of 28,000 16-bit words. The PDP-11 that transfers data to display has a core memory of 12,000 words.

Analog-to-digital conversion is required for input from the dedicated analog telemetry that feeds data from remote stations into RODS digital computers. Two A/D controllers allow inputs to be independently fed into both primary and secondary computers. Analog multiplexers provide 269 bipolar high-level differential-mode analog inputs at a scanning rate of 500 points/second.

Digital-to-analog converters handle output from the computers to telemetry. Again, two separate D/A controllers (each with 32 analog output channels working at a rate of 10,000 samples/second) are used, one each on the primary and secondary computers.

Digital data controllers handle input from 640 contact interrupts, 738 relays, and 160 logic levels, and outputs from 304 latching relays, 32 momentary relays, and 16 lamp drivers. Sixteen inputs are hardwired external high-priority interrupts monitored by the priority-interrupt controller. The digital data controllers can multiplex up to 4,000 points, and have input-output rates of 100,000 16-bit words/second.

The communications I/O controller has 110-baud asynchronous handlers and 2,400-baud and 40,800-baud synchronous handlers.

RODS' final subsystem, display, will provide its man-machine interface. Twenty-two consoles will be arranged on three floors at the Dittmer Center, most of them in the central dispatch area. Each console contains a combination of cathode-ray tubes, digital data displays, and CRT and digital data control devices. This subsystem can respond to four simultaneous CRT requests within a half-second.

Probably the most useful display for dispatchers ia CRT one-line schematic diagram of a given cluster of substations or transmission lines. The color-coded diagram on the CRT affords the dispatcher a quick overview of a selected segment of the power system. The BPA grid needs almost 300 diagram combinations to represent the system.

Software capabilities

Program name	Program & data storage (K-words) Main memory	Auxiliary memory	Central computer use	Response time	Execution frequency
Data acquisition	5*-25	50	variable	variable	variable from 1/sec
Display handling	10*-15	200	variable	0.5 sec	demand
CSM alarms	10	10	0.01 sec	3 sec	demand
Load frequency control	6*	8	0.015 sec	1 sec	1/sec
State estimator	13*	33	0.5 sec	3 sec	1/3 sec
Security monitor	40	80	2 min	10 min	demand
Voltage scheduling control	30	50	2 min	6 min	1/hour
Network power flow	40	80	2 min	10 min	demand
Scheduling group: Plant monitoring	10	10	1 sec	6 sec	1/hour
Plant scheduling	32	32	3 min	15 min	1/hour
Operation report	30	30	4 min	1 hour	1/day
Prescheduled input	5	5	35 sec	15 min	1/day
System load forecasting	20	20	90 sec	15 min	1/hour
Streamflow forecasting	30	30	15 sec	15 min	1/hour
Hydraulic summary	30	30	90 sec	1 hour	2/day
Joint intertie scheduling	6	6	30 sec	15 min	1/day

*Main memory resident

System expansion

Expansion capabilities are built into RODS by the system's modular design. In its 10-year useful lifetime, many advances are expected to be incorporated. Among those now being studied are power-system stability control, system restoration display and control, and hydrothermal economic dispatch.

Sure to come soon is more data. For example, the main-grid Scada I will be complemented by three subtransmission Scada systems scheduled for implementation at two-year intervals starting in 1974. And the existing low-speed digital telemetry from powerhouses eventually will be supplanted by dedicated data links for high-speed transfer.

The Corps of Engineers is developing a hydromet data bank that will plug into RODS. And BPA computers at the Dittmer Center will be linked with other utilities' computers.

Each of the subsystems can be stretched considerably without major hardware or system modification. Display consoles are built in modular formation for easy expansion or configuration changes. CRTs are mounted on rollaway carts for added flexibility.

Benefits

Benefit estimates for RODS have not been broken out of the total Dittmer package of benefits, which BPA lists as a decrease in blackouts, increased capacity sales, manpower savings, hydraulic optimization, and minimizing transmission losses. BPA estimates the transmission benefits to the Pacific Northwest at almost $400,000 annually, based on cutting peak system-transmission losses by 670 Mw, a 75% system load factor, and power salable 75% of the time at an average price of six mills/kwhr. Computer-directed hydro load scheduling and pondage management can add 570 Mw capacity that is unattainable with current manual and semiautomatic methods, says BPA, which figures the annual benefit of this at more than $5-million.

TRW Industrial Operations has two other real-time systems-control computer projects under way and in about the same stage (midstream) as RODS. They are with Arkansas Power & Light Co and General Public Utilities Co. ■