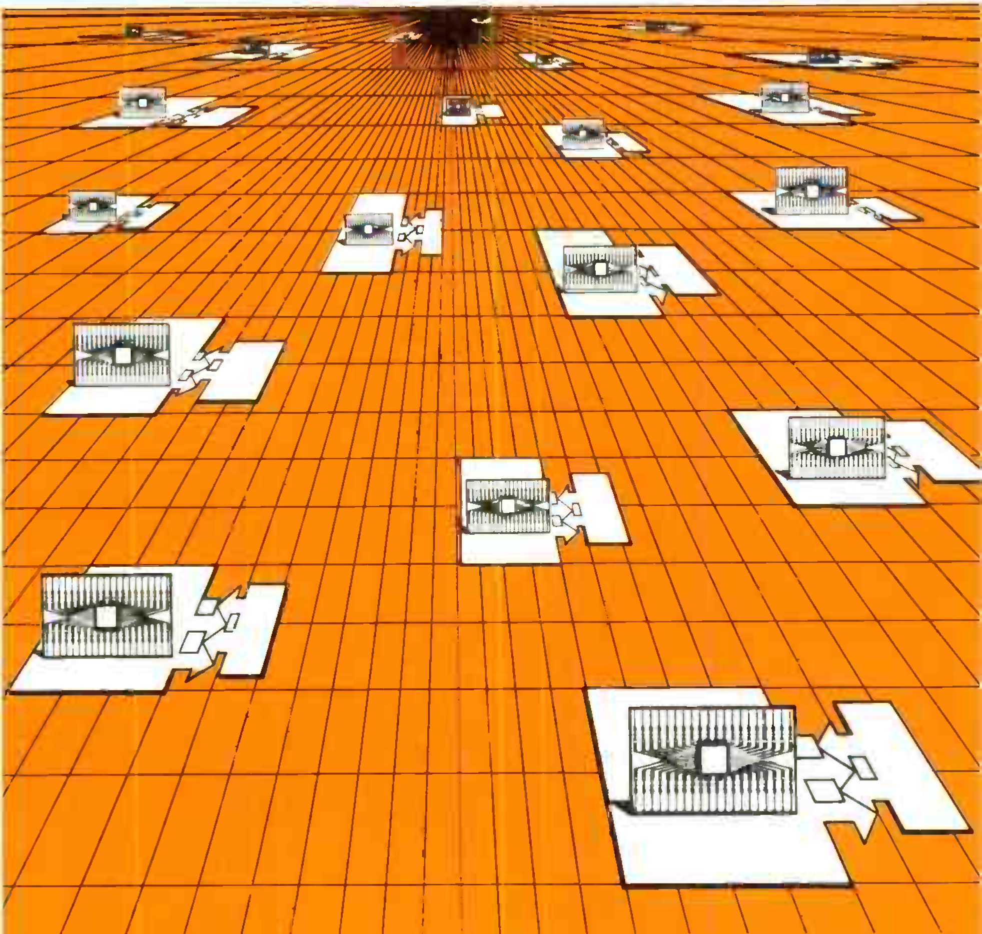
GTE LENKURT
DEMODULATOR
NOVEMBER 1973



THIRD GENERATION SUPERVISORY CONTROL SYSTEMS

Like other forms of technology, status monitoring is in a constant state of evolution, which can be seen in the implementation of new solid state technologies, including LSI, and the use of computers as an integral part of supervisory control systems.

The term "supervisory control" has come to mean the process of receiving digital or analog indications from a remote location, and sending a digital or analog command to a remote location. Some of the techniques used to achieve supervisory control are remote indication, telemetry, and telecontrol. Early systems usually included only the remote indication and telecontrol functions, representing only the digital forms of supervisory control, because transmission of binary quantities (on or off) was much easier than the transmission of analog quantities, and the need for analog measurement and control could not justify the high cost of early analog-to-digital converters. Later systems often included additional functions, especially in industrial applications where "process control" (the automatic control of a complex industrial process) was required. Data logging was also used where a historical record of system operation was required.

In hardware technology, supervisory control systems have evolved through two earlier generations, and are entering a third generation. The term "third generation" as applied to a supervisory control system is arbitrarily used to describe a family of systems utilizing LSI (Large Scale Integration) in the component circuitry, as well as having the optional facility to report into and receive controls from a minicomputer, or having a computer system and associated software as part of the system. Such systems, such as the GTE Lenkurt 51 series, are now being employed by users of telecommunications equipment for reporting and controlling of unattended microwave repeaters and for CDO (Community Dial Office) alarm reporting. Oil and gas companies use such systems for transmitting production data and for pipeline monitoring and control. Power utilities remotely control and monitor generating stations and substations from a centralized location, while simultaneously collecting grid data for load and frequency control.

First generation supervisory and control systems utilized electromechanical relays and rotary switches plus vacuum tube tone transmitters and receivers. This equipment was rugged and bulky but performed well, and there are hundreds of such systems still in service.

Second generation equipment utilizes integrated circuits and discrete components in place of relays, with solid state FSK (frequency shift keying) or AM (amplitude modulation) tone transmitters and receivers in place of vacuum tube types. The results have been a tremendous reduction in size (approximately 5:1) as well as an improvement in reliability with lower first cost and with less maintenance. Associated with the second generation of supervisory and control equipment are data loggers and custom designed minicomputers to gather information from many locations, and present this at a centralized alarm and control center.

Third Generation Families and Concepts

It is logical that a new generation of equipment should incorporate the best features of the previous equipment, as well as use the operating experience gained with these systems to add new and desirable features. The first step is to take a broad overview of individual alarm systems, control systems, minicomputer systems, etc., and to design a true "family" of systems with common modules such as encoders, decoders, and power supplies. The second step is to design the new families for the broadest areas of application by all users, whether in the telecommunications, oil and gas, transportation, utility, or any other field. This is achieved at low cost with the use of LSI (Large Scale Integration) chips, where up to 4,000 resistors, diodes, transistors, and other components can be deposited on a 1/4-inch square silicon wafer. Additional features can be built-in initially at minimum cost.

The third step in the design of new supervisory and control systems is to design them with the option to work into a centralized computer-based reporting and control facility, whether or not one is initially installed. Experience has shown that the high cost of software programming for the custom designed second generation minicomputer supervisory systems could be sharply reduced if a standard series of programs could be written. But, due to the wide diversity of applications for supervisory and control systems, this is not completely possible. What is possible, however, is to provide a broad selection of standard programs for specific functions such as alarm reporting, control with "check-before-operate," plus a "System Builder" program to allow the user's operation and maintenance department to readily add and delete alarm indicators, and control functions, as desired, without requiring more than a minimum knowledge of programming.

Remote Indication Systems

Remote indication systems differ principally in the mode of reporting used. The more common types are continuous reporting, time-slot reporting (polled reporting over a dedicated facility), and dialed reporting over a switched network. The latter is a variation of the polled type of operation.

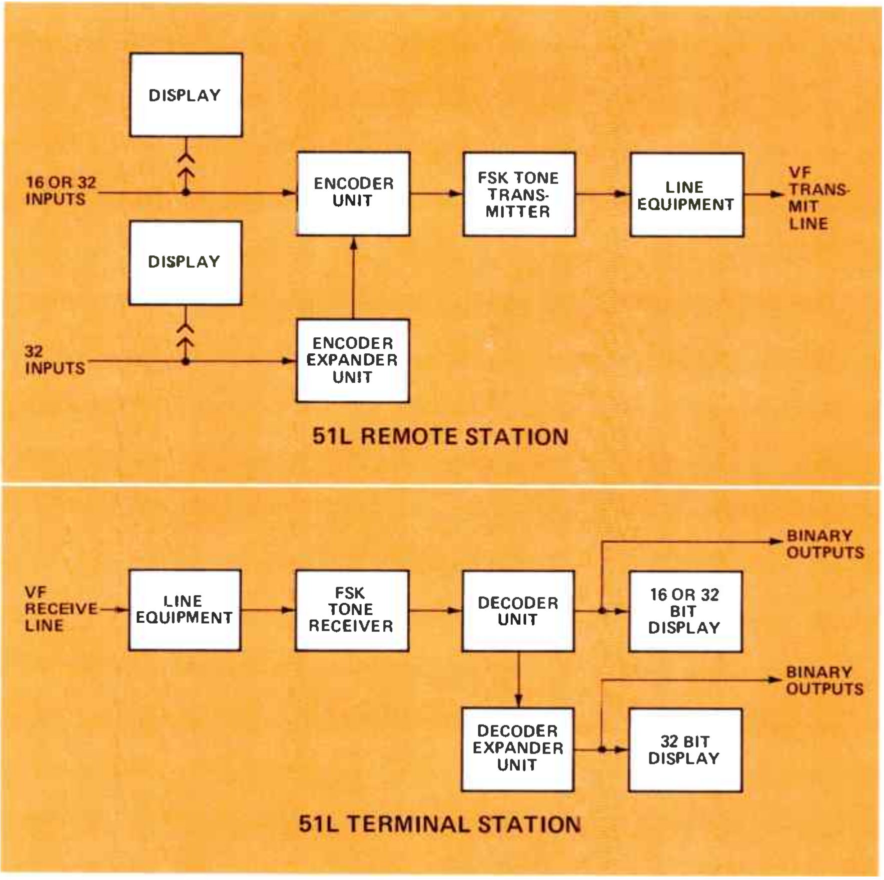


Figure 1. A continuously-reporting system gives an immediate alarm if the tone to the terminal station is interrupted.

Continuous Reporting

In a continuously-reporting system, each remote station reports the status of its input points continuously and automatically over a dedicated facility, using an individual tone channel between each remote station and its associated master station. The term "fail-safe" is often applied to such systems, because absence of tone causes an immediate alarm. Reporting is rapid, since the remote station can report continuously at a high baud ratio, and does not time share with other remote stations. One-way transmission is all that is required, adding more reliability to the reporting of information, as well as allowing a remote station to report to as many master stations as necessary. Modern continuous-reporting systems, such as the GTE Lenkurt 51L (see Figure 1), provide a wide range of reporting rates and station capacities, and find their greatest application where a relatively large number of status points per station must be transmitted in the minimum time.

Time-Slot Reporting

Time-slot reporting systems use one tone channel to report the status points of a number of remote stations. Since only one tone channel is used, the remote stations must time share the facility; that is, each station is allotted a time slot in which to report its information, hence the stations report sequentially by keying on their carrier and sending the station data, then turning off the carrier to allow the next station to report. Although speed of reporting is much lower than with continuous reporting systems, bandwidth requirements are correspondingly much lower. Consequently, this type of operation is suitable for systems having many remote stations of fairly low number of points each, where system reaction times allow a slower reporting rate. There is also an economic advantage in that a simple master station can receive indications from many remotes, rather than requiring a separate master for each remote as in the continuous reporting type.

To ensure time sharing, the remote stations must be synchronized with each other. This is accomplished in systems like the GTE Lenkurt 51M alarm reporting system by sending a momentary signal from the master to all remote stations after each complete system scan to reset the crystal-controlled counters in each remote (see Figure 2). The important advantage of time-slot reporting as used over a polled system is that reporting ability is not lost if the outgoing synchronizing signal is lost, since the crystal-controlled remote stations will remain synchronized for several hours and will continue to report.

Because each station in a time-slot reporting system must report within a certain time window, station-point capacity is limited. A system such as the GTE Lenkurt 51M may be arranged to report 26 alarms per remote station, allowing up to 63 stations per tone channel, for a system capacity of 1638 supervised points. If more points are required, two or more remote units may be located at the same station, each having its own time slot. Each remote station in the time-slot system is identified by a unique 6-bit station address.

To overcome the main disadvantage of time-slot reporting, a change of state reporting sequence may be used in which any station having a change of state, which might constitute an emergency condition, will report immediately in the time slot being transmitted at the time by sharing the time slot with the designated station. This is possible because each station reports in the center one third of its time window, leaving the other two thirds empty of any transmitted signal. It is the last one third that is used by any station having a change of state.

Polled Systems

Polling refers to the method of operation where the master station

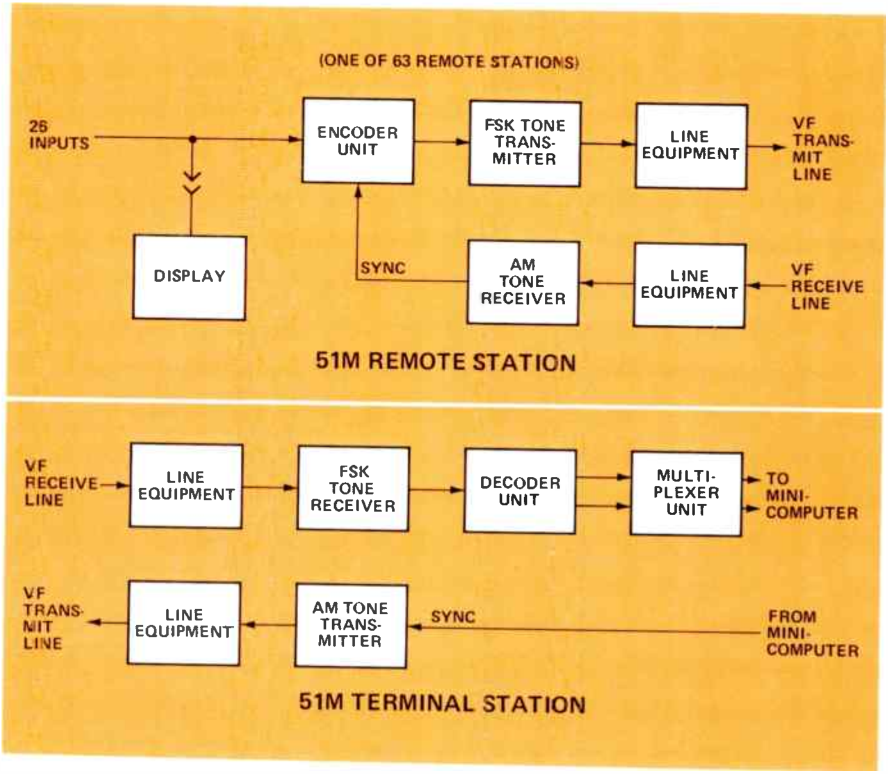


Figure 2. Time-slot reporting systems use one tone channel to report the status points of several remote stations.

sends a request to each remote station in turn to report its status. A two-way transmission facility is required, an outgoing path for the interrogation signal and an incoming path for the station reports. This type of operation has the disadvantage of being disabled if either direction of transmission is lost, and is therefore often considered unsuitable for certain applications. For example, a polled system monitoring a microwave radio system can be disabled by a communications failure just when reports of the failures are vitally needed by maintenance personnel.

Dialed Systems

Dialing remote stations through the telephone switched network is a variation on the polling method of operation. However, instead of requiring a dedicated two-way channel, a non-dedicated telephone link is used which is very economical in terms of channel requirements because the channel is accessed only when needed. The natural application of dialed systems is in the monitoring of community dial offices by the telephone companies.

Unattended Community Dial Offices (CDO's) normally report alarms via physical facilities to their nearest attended office. To provide 24-hour coverage, simple lamp displays often appear on telephone operators' switchboards. To provide a high service level with the increased cost of "call outs" (when a repairman has to be sent out), it is becoming apparent that much more information is required about the specific conditions in the CDO, and that this information should be analyzed by knowledgeable maintenance personnel so that the correct type of repairman can be sent to perform the job. Centralization of CDO alarm information, particularly in the off hours, is therefore becoming a priority item.

As each CDO is readily accessed via the telephone switched network, a telephone call to a specific number in each exchange can access a continuously running encoder to which up to 32 office alarms may be connected. Each station transmits its address and alarm status to a common decoder at the central location.

Automatic dialing of each CDO may be arranged on a pre-determined period, either utilizing a bank of repertory dialers, storing up to 25 numbers each, or automatic dialing under minicomputer control with numbers stored and output sequentially.

Telemetry Systems

Telemetry, like remote indication, involves the transmission of information from a remote location to a master station for use by the operating personnel. The difference is that where remote indication refers to two-state indications, i.e. on/off or open/close, telemetry refers to analog quantities which can take on a continuous range of values. Earlier systems sometimes transmitted the quantity by analog methods, such as variable frequency, pulse amplitude, or pulse position modulation. Many sources of inaccuracies as well as susceptability to noise made such methods undesirable.

Telemetry systems now transmit analog quantities by converting the quantity to digital form at the originating site, and transmitting the resulting digital signal by methods previously described for remote indications. Using this method, errors can be eliminated through digital code checking so that inaccuracies do not creep in as in analog transmission.

With today's low cost of analog-to-digital converters, telemetry of numerous quantities previously not considered necessary becomes practical. A change in philosophy is taking place in which remote measurement takes a much more prominent place in systems operation and maintenance. Telemetry has long been used for measurements such as pipeline pressures, flow rates, task levels, electrical distribution quantities such as current and voltage, and other operating system parameters.

It is now being used for many other purposes such as preventative maintenance, traffic measurements, environmental data gathering, and other tasks which may not be classified as essential, but do increase the efficiency of the operation and provide services not available previously.

Modern telemetry systems are all solid state and can be arranged to

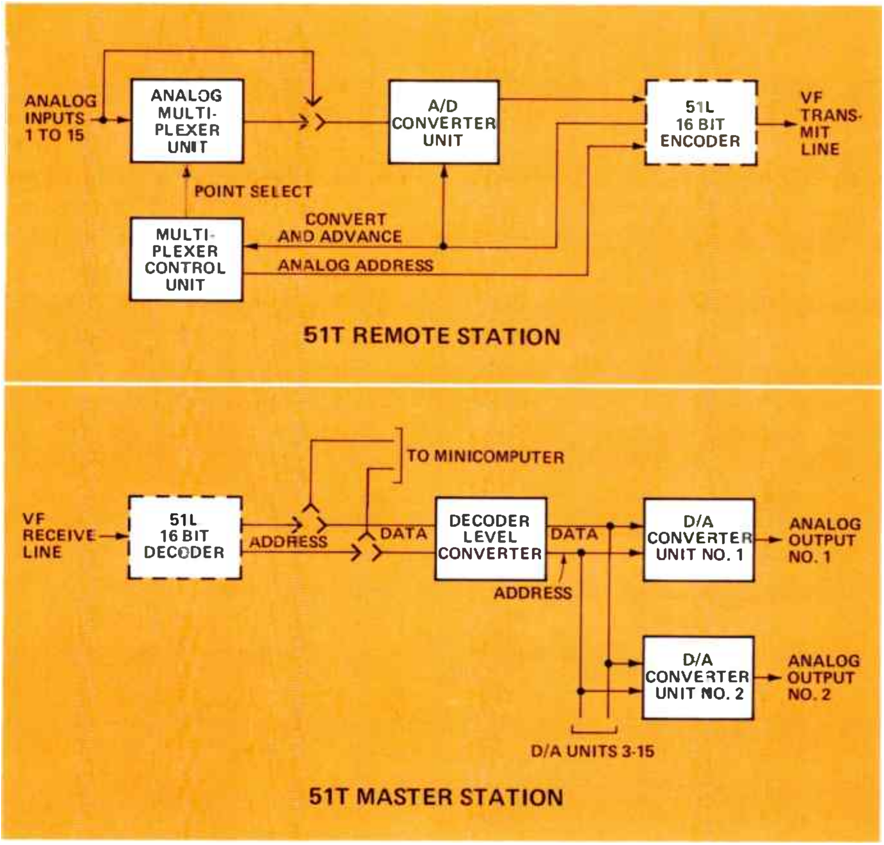


Figure 3. Telemetry systems convert analog quantities to digital at the remote station for transmission to the master station. At the master station the quantities are decoded and displayed in the original analog form.

transmit a large number of different analog quantities very efficiently and at speeds adequate for the process or operation being monitored. A telemetry system, such as the GTE Lenkurt 51T, is an assembly of analog-to-digital (A/D) converters, analog multiplexers, digital-to-analog (D/A) converters, and ancilliary equipment, all designed to work into a digital transmission system such as the GTE Lenkurt 51L remote indication system. In certain applications, where rapid updating of telemetry information is not required, a time-slot reporting system, such as the GTE Lenkurt 51M remote indication system may be used as the digital transmission system. The telemetry system is designed to accept analog data and convert it to digital form for transmission. At the master terminal, the incoming digital informa-

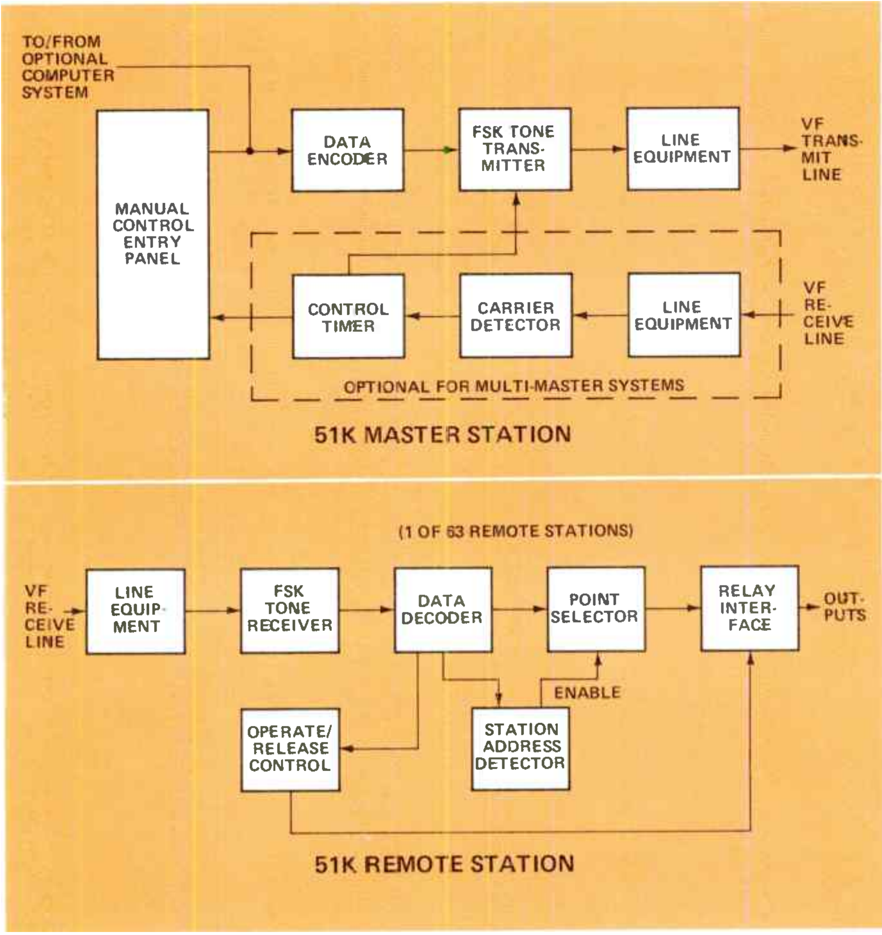


Figure 4. Telecontrol systems transmit control commands to remote stations to perform such functions as activating relays and operating valves.

tion can either be displayed in decimal form, reconverted to analog form, or input into a minicomputer (see Figure 3). The extreme variability of telemetering requirements make great flexibility, mandatory.

Typically, a number of analogs of different characteristics must be converted to one standardized level in appropriate interface units. The conditioned analogs are sequentially scanned by an analog multiplexer with the resulting output being presented to an analog-to-digital (A/D) converter. The digital output, which usually has an 8-bit to 12-bit binary resolution, is transmitted by status systems such as the 51L.

Figure 5. Typical control panel for a telecontrol system.

At the 51L master terminal the output may be processed by a computer and/or displayed digitally. If more than one analog value is being scanned, an analog address is included in the data word. This address is recognized by a decoder which routes the data word into the appropriate readout.

Similarly the data may be routed to digital memory units incorporated in digital-to-analog (D/A) converters. The analog address in this case accesses the appropriate digital memory, which, in turn drives the associated D/A unit, resulting in a continuous analog output from each D/A converter equipped.

Telecontrol Systems

Telecontrol systems are used to transmit control commands to remote stations to activate relays, operate valves and all forms of remote control functions. The term "telecontrol" itself is normally associated with transmission of two-state binary control commands while set-point control is more identified with transmission of an analog control command to a remote station. Both types require a very secure control code to prevent errors that could result in operating the wrong valve or turning off a microwave transmitter. A typical telecontrol system diagram is shown in Figure 4. This system provides control of up to 128 latching or non-latching relays at each of 63 stations. The commands are transmitted to the remote stations via a common FSK tone channel.

The structure of control command allows the remote stations to perform synchronization, timing and noise tests. In addition, double scan protection virtually eliminates false control operation due to transmission errors. The control decoding stations are arranged to inhibit simultaneous operation of more than one control relay. Any attempted simultaneous action may be reported to the control station as "Command Inhibit" indication.

Use of optional latching relays to interface the control decoders to the controlled equipment ensures the magnetic storage of all control functions in the event of remote station power failures. These are particularly used with set-point storage.

When required, additional system security is obtained by operating the 51K telecontrol system in conjunction with a status reporting system to provide a "Confirm before Operate." The status lamp on the status reporting system confirms that the correct control point has been selected. The "Execute" button may then be pressed to carry out the control function. A typical control panel for such a system is shown in Figure 5.

Modern supervisory control systems make use of LSI technology to provide "third generation" equipment at lower cost. These systems, through LSI, are able to provide the flexibility and features demanded in the variable and often complex applications seen in the world of supervisory control.

BIBLIOGRAPHY

Dahlbon, C.A., "New Supervisory Control System," *Bell Laboratories Record*, August 1955.

"Remote Control and Supervision of Industrial Operations," *The Lenkurt Demodulator*, September 1955.

Rochat, R.A. and W.O. Hawk, Jr., "Modern Supervisory Control Systems are easily expanded," *Transmission and Distribution*, September 1973.

"Supervisory Control," *The Lenkurt Demodulator*, February 1968.

"Supervisory Control, 51 Series," British Columbia, Canada: GTE Lenkurt Electric of Canada LTD., 1973.

"Third Generation Supervisory Control Systems," British Columbia, Canada: GTE Lenkurt Electric of Canada LTD., May 1973.

GTE LENKURT
1105 COUNTY ROAD
SAN CARLOS, CALIFORNIA 94070

ADDRESS CORRECTION REQUESTED

Bulk Rat
U. S. Post
PAID
San Carlos,
Permit No.

GTE LENKURT

VIDEO, VOICE & DATA
TRANSMISSION SYSTEMS

The GTE Lenkurt Demodulator is circulated monthly to selected technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions. Permission to reprint granted on request.