The Lenkurt DEMODULATOR

FEBRUARY 1968

Telecommunications Provides Solutions for Industry's Problems of Remote Supervisory Control

The increasing complexity of modern society is perhaps best reflected in the areas of commerce and industry. It is here that the growing demands for goods and services — both quantitative and qualitative — by an exploding population is most strikingly illustrated. A major result of this rapidly increasing demand is a trend toward the monolithic among suppliers. Huge chains of supermarkets have replaced the neighborhood green grocer and butcher shop. The corner drugstore of a generation ago has given way to corporately-owned emporiums that merchandise everything from medicine to toys.

This same trend is also reflected in our utility industries. Where formerly fuel and power were supplied to consumers by locally-owned, cooperative concerns, they are now served by distributors whose operations encompass entire geographic regions. For example, most of the northeastern United States gets its electric power from a single source; also, most consumers in the American Southwest subscribe to the same monolithic natural gas supplier.

As these utility networks have grown, their transmission lines — pipe or wire — have extended more and more into remote areas — many of them virtually inaccessible. This extension has necessitated the establishment of relaying substations or pumping facilities in some of the remotest areas of the world. The obvious problem this situation presents is one of control.

Since it is neither humanly plausible nor economically feasible to operate these facilities manually, another means must be found. To meet this need the telecommunications industry has developed electronic status monitoring and remote control equipment, commonly referred to as supervisory systems.

Maintenance vs Control

The term status monitoring may be applied to a number of devices; some are quite familiar to us, others are highly unusual and specialized. Automotive fuel and pressure gauges, even the little red lights on the instrument panel which indicate high beams, low voltage, etc., are examples of simple status monitoring devices. There is a direct relationship between these simple applications of status monitoring and the highly sophisticated methods of reporting and control employed in power transmission and petroleum pipelines.

In discussing these systems, however, a distinction must be made between simple alarm systems and complete supervisory systems. In the case of the former, the main consideration is remote indication of "off normal" situations. This draws attention to potential trouble spots so that corrective action may be initiated. On the other hand, the most sophisticated supervisory systems report such quantitative information as flow, pressure, temperature, or voltage, and perform such functions as opening and closing circuit breakers, selecting basebands

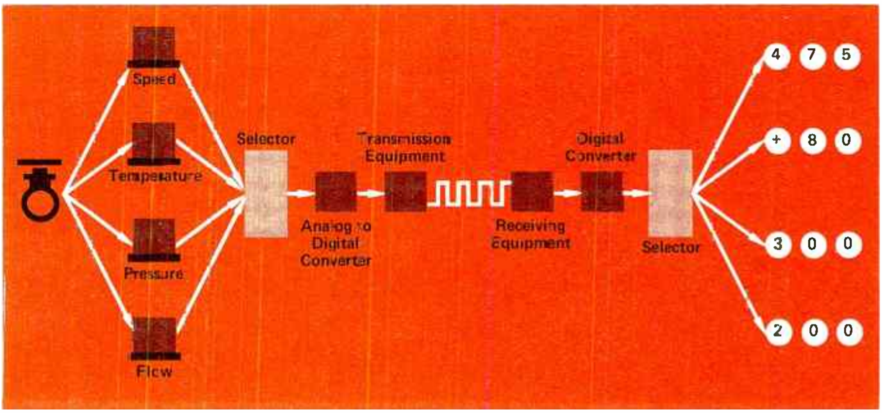

Figure 1. Simplified diagram of a typical supervisory control system.

for microwave radio, starting and stopping pumps and operating valves in the pipeline industry.

Microwave, A Typical User

A typical area in which simple maintenance-type monitoring is employed is in microwave radio transmission. Different functions of remote sites are scanned, and a simple stasis-change situation is continuously reported to a centrally located master. When change is indicated, the operater determines its nature and takes appropriate action. He may either attempt to correct the alarm situation electronically, or it may be necessary to dispatch maintenance personnel to the trouble spot.

In microwave radio, a common emergency situation might be a commercial power shortage or outage; in such cases one of the functions of monitoring systems is to switch to emergency dc power supply and begin monitoring that supply. If a predetermined critical output level is reached, the control station automatically shuts down the microwave system to prevent damage. While these maintenance-type systems do indeed come under the broad scope of status monitoring, the major concern here is with systems which perform control functions and how they do it, particularly in the electric power transmission and petroleum pipeline industries.

Typically, these systems are characterized by a centrally located master station and a number of remote stations. Ideally, the systems may employ cable, microwave radio, telegraph lines (open wire), or leased voice-plus-data lines. In most cases, the master station automatically and continuously interrogates the remotes. The remote stations in turn respond sequentially – usually indicating change or no change. Status of functions monitored by remotes is indicated at the master station on a lighted display panel or by means of audible alarms.

Different systems employ various electronic signaling techniques – some use frequency shift keying, others pulse code modulation, while still others use phase shift modulation. In all cases, stasis and change are translated as ON or OFF, or OPEN or CLOSED. Besides simple status surveillance, some systems also incorporate certain control functions, such as: activate emergency power supply, trip circuit breakers, open/close valves, or start/stop pumps. Still more complex systems involve telemetering analog data such as actual meter readings.

From India to the Alps

Petroleum pipeline networks criss-cross some of the most remote and rugged terrain in the world – the Appalachians of western Pennsylvania for instance, or the entire northern section of the Indian subcontinent. There is a pipeline in Europe which originates at Trieste, Italy on the shores of the Adriatic, crosses the Austrian Alps and terminates at a tank farm in Ingolstadt, West Germany. In all three cases status monitoring and remote supervisory control are vital to the success of the entire operation. Volumetric output, flow rate, pressure, and temperature are monitored constantly; and valves are opened and closed, pumps activated or stopped automatically – hundreds of miles from the nearest civilization.

Although techniques and equipment vary considerably from one pipeline complex to another, the conditions monitored and the functions performed are substantially similar; this is equally true of either natural gas pipelines or crude oil carriers. Typically, they combine transducers, analog collectors, analog to digital (A/D) converters, digital collectors, digital transmission of status information, computerized storage, and visual/aural display facilities. (See Figure 1)

Quiescent-vs-Scanning

Early status monitoring systems were of the quiescent type – that is, they remained inert until an alarm situation occurred. And most had no control functions. Obviously, one

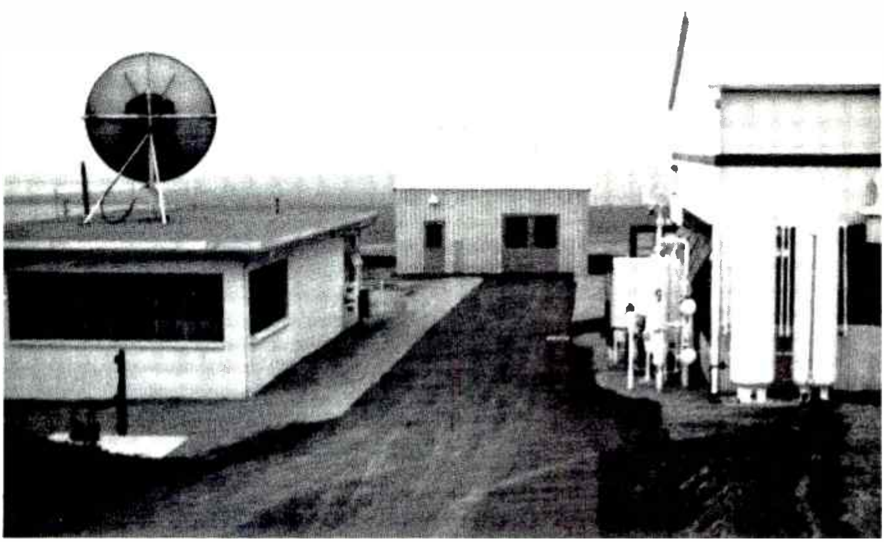

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Figure 2. Control room at a pipeline pumping station.

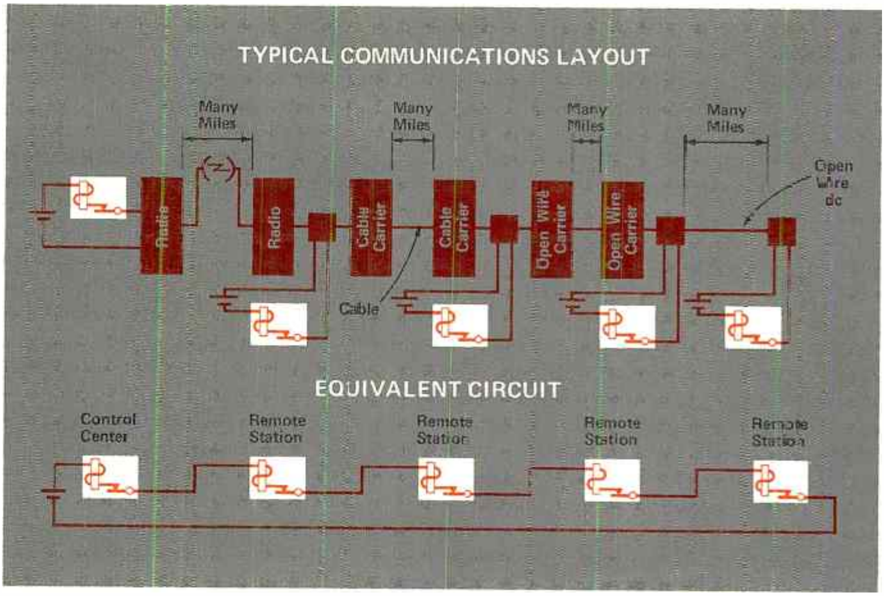

Figure 3. Typical communications layout for a supervisory system as might be used in pipeline networks.

problem, among others, was maintenance. It was virtually impossible to tell if such a system were operable unless it was reporting an alarm or malfunction.

Such systems have gradually been replaced by continuous reporting or sequential interrogation-type systems. These not only obviate the maintenance problems inherent in quiescent systems, but also provide more versatility and flexibility – particularly in the area of control functions. Furthermore, continuously scanning and reporting configurations more readily lend themselves to interfaced operation with digital transmission systems and computerized collection and storage of transmitted data.

As pointed out earlier, these supervisory control networks consist of one or more master stations and as many as 100 or more on-line stations – usually called slave stations.

In such scanning systems control of the scan is the responsibility of the control station or stations. The master station is able to alter the scan as required; that is, it may interrogate the outstations either continuously, sequentially, or randomly. Also, various functions of the different outstations – flow rate, metering, pressure, etc. – may be scanned.

The majority of high-speed supervisory systems use pulse position modulation (PPM). PPM is a type of pulse-time modulation in which instantaneous samples of a modulating wave are caused to modulate the position of a pulse in time. However, some also employ other techniques, such as pulse duration modulation, time phase modulation, or pulse code modulation. Using the binary digit system, PPM indicates 1 when a pulse is present and 0 when absent. The prime advantage of PPM is that all pulses are of the same

Figure 4. Electroluminescent map of Montreal-Hauterive power transmission network.

duration, hence data is transmitted in the minimum time.

A Model Supervisory System

A model supervisory control system as used by a pipeline, for example, should prove helpful in understanding the various processes involved and functions performed. Characteristically, status monitoring systems employ transducers, encoders, selectors, a communications loop, digital converters, and display facilities. More recently, there have been innovations in the application of computers.

Ideally, the master control station will be centrally located along the pipeline route; in some cases however, as in the Transalpine Pipeline in Europe, there will be two control stations, one at each terminus. Pumping and booster stations are spaced along the line according to terrain and path considerations. Slave stations of the supervisory system are collocated with these remote substations.

When the control station initiates interrogation, response begins with a sensory device (transducer) which meters and reports the requested variable – psi, degrees C, volumetric flow. This data is then fed through an analog selector to an A/D converter; the response is then transmitted through the communications loop to a digital converter and fed through a selector to the display facility. Display facilities are read-out dials, lighted panels, or, in more sophisticated systems, flat-fold print out.

Encoding for Telemetering

Although many types of encoding devices are used, a typical one is the digital voltmeter (DVM). This type is particularly effective since most transducers transform data into a current or voltage analog which is readily converted to digital form. The most frequently used operational techniques in DVM's for conversion purposes are digital servo, voltage-to-frequency, ramp comparison, and successive approximation. In connection with the model system, only the first of these will be discussed here. Digital servo techniques are also employed in supervisory control functions.

A servo element is graduated so as to follow a changing input voltage (or current). A feedback signal is then compared with the input, and when a null is reached the tracking element stops. Hence, the position of the tracking element can be read directly in digital form. These tracking elements are frequently in the form of stepping switches.

An earlier form of encoding device was the cyclic disc (see cover), with photo cell or carbon brush pick-off.

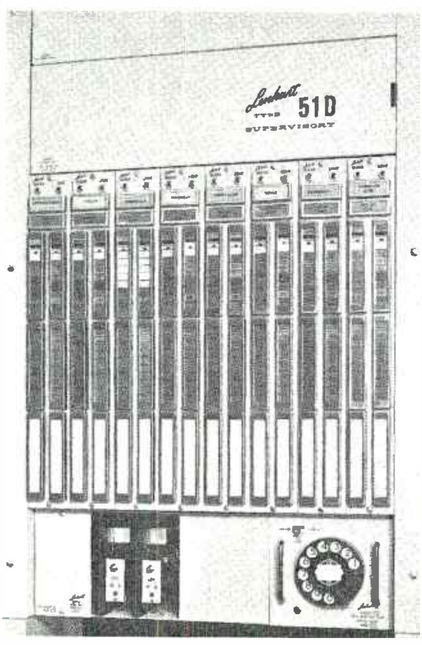

Figure 5. Alarm display panel of Lenkurt 51D supervisory system.

Using this digital disc, a remote station could scan each transducer and receive a digital reading for each variable reported. Although lately the cyclic disc has fallen into disuse, the trend toward computerization in master stations may bring it back into more widespread use. This is particularly likely since the use of discs obviates the requirement for A/D conversion found in present systems.

A Model Communications System

Once the information has undergone conversion from analog to digital form it must then be communicated to the control center from the slave stations – and vice versa. This function may be performed by various systems employing any ordinary 3-kHz voice channel. Ideally suited to such a system is the Lenkurt 25A Data Transmission System which has a 200 b/s capability for data transmission and is also adaptable for relaying of supervisory control commands. In cases where a higher bit rate is necessary or desirable – for example, computer-to-computer transmission – the Lenkurt 26C Duobinary data set is ideal.

Most communications systems used in status monitoring employ MARK (1) – SPACE (0) techniques with or without a return-to-zero function. Hence, the ordinary digital system is used wherein, say the number 4, or any decimal equivalent, is preprogrammed to elicit a desired response from the equipment under control. At the same time, but in the other direction, specific decimal equivalents indicate specific conditions, such as flow rate, temperature, or pressure. All such systems provide extremely high security from errors – most are virtually error free.

Readout

Once the reported data undergoes reconversion to digital form, it is

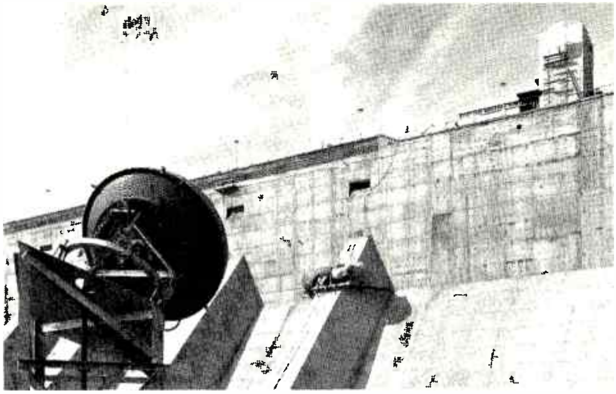

Figure 6. Microwave antenna and reflector as used by a hydro-electric dam.

picked up by a selector and relayed to the display facilities. The input is in digital form and any "off normal" data automatically triggers the alarm system. When this occurs, the operator at the control center initiates corrective action.

Also, all incoming data is automatically logged. The purpose of the alarm logger is to maintain a permanent record of the operation of the system. Intervening time and the sequence in which alarms are reported enable operators to evaluate operating techniques and reporting procedures. A typical log is shown in Table 2; others also indicate such information as station status on an hourly request basis and print out alarm status in red rather than black as in normal situations.

Function and Control

Pump engines, electronic valve controllers, booster pumps, etc., are all preprogrammed so as to respond to electronic commands from the control center. For example, to operate a bypass valve, the operator at master control in our model system must select the remote using rotating switches, pushbuttons, or thumb-wheel switches. He then selects the individual valve to be operated and the function to be performed. Finally, he cues the transmission system and transmits a command:

Start of Message (SOM) 01 2 10 (EOM) End of Message.

This might be translated as:

(SOM) Station 1 (01), Open (2) Bypass valve (10) (EOM).

The remote station then responds in kind. This is followed by a transmission that the requested function has been performed. The master station verifies the report and returns to status scan operation.

The prime functionary here is also a servo device. In response to a predetermined signal from the control center, the servo simply activates an electric motor which in turn performs the desired task, such as starting a booster pump or adjusting a valve. Another type, usually found in storage tanks, operates in conjunction with a float, and automatically stops the fluid input when a predetermined tank level is reached.

Conceivably then, one man at an adequately equipped control center is able to operate a pipeline network covering hundreds of miles. Furthermore, terrain, climate, and accessibility are no longer concerns — except

Controls:		
Engines	Stop	These controls are primarily for emergency occasions but the engine 'stop' controls may be used to adjust the throughput by stopping engines individually. Engines are started locally.
Inlet Valve	Open Close	
Discharge Valve	Open Close	
Bypass Valve	Open Close	
Repeater Mainline Valve	Open Close	
Intermediate Mainline Valve (Moran)	Open Close	
Security Sheet:		
Tank Level		Printout starts either, (i) On demand w/o reset (ii) At a predetermined time. (iii) On demand with reset
Flowmeter		
Total Throughput (per station)		
Flow Data Reset		
Monitoring: (Operational State)		
Booster Pumps (Running)		These functions are indicated by lamps lit on the dispatcher's graphic diagram – 'auto/manual' refers to the start of the balance tank stations where engines are controlled by the tank levels. During control 'off' state, telemetering from the site is maintained.
Main Pump (Running)		
Inlet Valve		
Discharge Valve		
Bypass Valve		
Auto/Manual		
Tank on Flow		
Repeater Station Valves		
Intermediate Mainline Valve (Moran)		
Dispatcher Control "Off"		
Duty Generator		
Alarms:		
Inlet Pressure (low)		The alarms listed are indicated by individual signals on the display panel. These alarms are accompanied by a flashing light and a bell. The 'multiple' alarm is a composite alarm to the dispatcher alarming functions not listed here, e.g. high water temperature, low lubricating oil pressure, etc.
Discharge Pressure (high)		
Balance Tank out of Band		
Tank Level		
Fire in Oil Area		
Equipment Room Temperature Rise		
Entry (Unauthorized)		
Duty Generator		
Emergency Generator		
Viscosity (High)		

Table 1. Some Functions of a Typical Pipeline Supervisory System.

of course to installers of the original equipment.

Power Companies, Too

In actual function, supervisory systems used by power transmission companies differ little from those employed in petroleum transport systems. The similarities between flow and current, pressure and voltage, etc., are easily seen. In general, however, reporting and scanning speed are considerably more important considerations in power transmission.

Sudden power outages – such as the one which darkened the American Northeast in 1965 – are illustrative of the need for viable supervisory control systems to power and light companies. Such a system, the Lenkurt 51D, is now in use in the Montreal-Hauterive complex of one of Canada's large power companies. This 750 Kv system utilizes both microwave radio and protective relaying systems as back-up for the power transmission lines. The microwave system features 13 repeaters spaced 15 to 50 miles apart.

The network also uses frequency diversity transmission and reception and provides more than 600 channels. Obviating the need for intermediate mechanical relays, the system employs the Lenkurt 937A Protective Relaying System to operate circuit breakers. This system has the advantage of reducing response time from 20 ms to 8 ms. Also, special circuits ensure that anything greater than a 5 dB increase

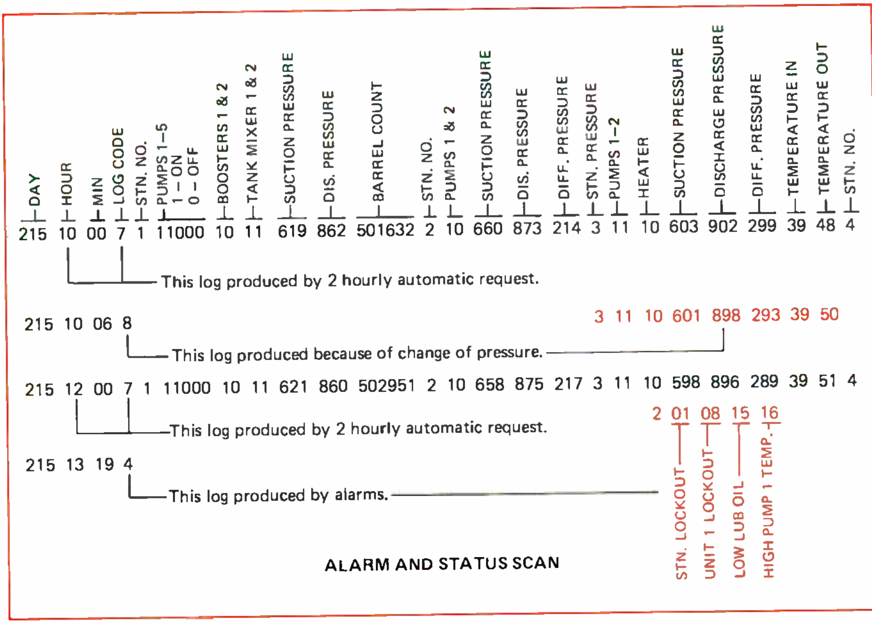

Table 2.

in noise or carrier channel frequency will not cause false operation of the equipment.

The supervisory control system itself is capable of reporting up to 28 alarm situations from each of the slave stations along the line to either Montreal or Hauterive or both. Fully automatic operation is the main feature of the system. Fault conditions are automatically reported to control stations without the need of an operator; this is also true when conditions return to normal. Faults at mainline sites are displayed at both Montreal and Hauterive on a large electroluminescent map. (Figure 4)

Each site is scanned and reported every half second. An electronic clock and scanner at repeater sites sees an open circuit on each alarm lead; an indication of a fault opens the lead to the scanner which then shifts the frequency of the tone channel. This in turn transmits the fault data to the reporting center where clocks and decoders automatically synchronize to the remote stations and translate the alarm condition onto the illuminated display panel. Each station has 25 lamps to indicate different functions associated with that station. (Figure 5)

Interfaced with the supervisory system, a data logger notes all alarm conditions. These in turn are printed out on flat-fold paper by an electric typewriter capable of speeds up to 350 lines per minute. Information includes station name, fault, time and date.

A salient feature of the supervisory system is solid-state electronic equipment with module-type units for quick and easy replacement in the field. Further, all equipment is battery operated with a 24 hour reserve in conjunction with self-starting diesel generators which automatically come into play when commercial power fails. Continuous interrogation of slave stations with dual reporting in two directions simultaneously to two different control centers is another important feature. Buildings, towers, etc., are engineered so as to provide maximum immunity to the elements. The purpose of the system is to provide or maintain service during power outages.

Load Shedding

In dire emergency situations, a last ditch measure taken by supervisory control systems is to gradually shed the power load on the network. Of the many variables monitored, generator frequency is one of the most critical – a sudden drop in generator frequency is indicative of power overload. Preprogrammed servo devices automatically shed 25% of the load when frequency drops to 59.5 Hz. Should the frequency continue to decline, 50% of the load is shed at 59 Hz; the system completely shuts down if the generator frequency reaches 58.5 Hz.

However, since power companies are in the business of supplying – not reducing – power, these are to be considered as measures taken only when all else fails. In less drastic situations simple load transference or rerouting is usually sufficient.

Looking Ahead

As with other technologies, status monitoring is in a constant state of evolution – systems become increasingly complex and, paradoxically, more efficient. At the present time, probably the most striking innovation has been the transition from electromechanical circuitry to solid state devices. This change has resulted in reduced maintenance and increased reliability. Miniaturization has allowed more efficient use of shelf and rack space – hence, reduced operating costs resulting in greater profits to users. Further, the transition from analog to digital transmission of data has increased efficiency by eliminating one of the translation phases necessary in older systems.

In the near future, complex supervisory systems will undoubtedly be employed in such increasingly diverse areas as Rapid Transit Systems where instantaneous switching is a prime requirement; or small telephone companies characterized by unattended Community Dial Offices. Down lines may be immediately reported and corrective action initiated instantly through supervisory control facilities. Moreover, status monitoring is finding ever greater application in communication satellite programs.

Within the systems themselves we shall see a growing trend to solid state configurations and more widespread interfacing of existing equipment with high speed computers.

In the end it must be concluded that the potential growth of status monitoring and its applications is as limitless as that of technology itself.

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