1. The array of yard designs was narrowed to a choice between two specific, new yard designs.
2. The yard was designed to handle 6,000 cars on a peak day.
3. The classification yard was designed to work together with the TVM yard and was dedicated to serve only a group of eight TVM tracks.
4. A trim end was designed with a capacity equal to that of the hump and with great flexibility, few conflicts, and low cost.
5. The minihump was designed with the trim end east of the on-line departure yard and later changed to be beside the classification yard west of the TVM group. With this change there will be fewer conflicts at the trim end.

Employee acceptance of the new yard and its new systems may pose problems when the yard is opened. It is not too early to start a program of familiarization for the employees. First, sessions could be held with union leaders and their local representatives to tell them what is being planned and why and invite their cooperation and suggestions. Second, when possible, some of the new devices and systems could be set up in a demonstration mode so they could be tried. Third, comprehensive training programs could be offered before the yard is opened. The training sessions should feature hands-on training by using actual devices and procedures. A program along these lines will help to overcome possible problems of nonacceptance.

ACKNOWLEDGMENT

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Advice was also given by William V. Williamson and Barney Gallagher of Southern Pacific Transportation Company during 1981 and Hubert Hall of the Atchison, Topeka, and Santa Fe Railway Company in 1982. Assistance was received from SRI International, represented by Peter Wong. The final design is the result of the high degree of cooperation, understanding, patience, and hard work of all concerned.

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A Modular Approach to Classification Yard Control

ROBERT KUBALA AND DON RANEY

A design is described that focuses on existing yards. It provides basic control functions and is cost-effective, expandable, and maintainable. The distributed system provides natural partitioning, expansion, system flexibility, and modularity through the use of microprocessors. Hierarchical relationships of each function within the yard are explained and illustrated. Suggested hardware for the system includes racks, chassis, and power supplies. Estimates of facility requirements such as power, floor space, and heating or cooling are also provided.

In late 1979 the need became apparent for a yard-control system with characteristics somewhat different from those of existing computer-based control systems. Most new control system development had been targeted for new yards designed for increased levels of automation and functional capability. These systems provided a level of control that could not be obtained by using previous technologies. However, these systems did not lend themselves to applications in existing yards where a high degree of automation was impractical either because of existing field conditions or the configuration of the yard. Therefore a project was launched to analyze existing control systems and determine whether a system could be developed that would provide basic control features in a configuration more applicable to an existing yard facility.

DEFINITION OF FUNCTIONS OF A YARD-CONTROL SYSTEM

The first step in the project was to identify and define those functional features that might be required in the target system. The track and equipment layout of a yard is shown in Figure 1. A list and brief description of each function required of the control system follow:

1. Cut detection: The control system must detect a cut after it has been separated from the train. The presence of the cut must be detected soon enough to allow characterization of the cut (see item 2).
2. Cut characterization: Each cut must be characterized with respect to length, axle count, number of cars, weight, and rolling resistance. Characterization must be complete before the cut enters the master retarder.
3. Cut tracking: The system must track the movement of cuts through the control area. If a cut proceeds on a path other than the intended path, an alarm should be generated. The track on which the cut leaves the control area should be recorded for reporting purposes.
4. Switch control: The system must provide for automatic switch movement to ensure that each cut is routed to the requested classification track.
5. Distance to couple (DTC): The system must maintain a record of distance from tangent point to standing cuts on each classification track. This information is derived from a car-count algorithm or from electronic hardware measuring distances.
6. Exit-speed calculation: Given the cut characteristics, cut destination, curves, grades, elevation drop, distance to go on the classification track, and target coupling speed, the system must

System Flexibility

Dispersion of a system into a distributed set of substantial subsystems is an answer to general problems universally found in large industrial and military systems. An example of this type of distribution is the public telephone system as it was recognized a number of years ago.

At one time, the Bell System sought to grow and maintain its large network by maintaining control over all aspects of design, manufacture of components, installation, and operation. As technology advanced, Bell engineers recognized that the approach was unworkable; it amounted to a replication of a highly evolving technology-based economy within one organization.

There was another way, namely, not to try to predict and control everything but to construct the whole system out of important subsystems whose functions and interfaces to the system could remain constant over the lifetime of the system. This approach has been successfully applied by the telephone companies. As technology advanced, the newer, more advanced systems, which were cheaper and more reliable, could be incorporated into new subsystems with the expected economy and performance. Because the interface (electrical levels, signals, connector dimensions, and so on) remains constant, the system continues to work without disruption. The system still has ultimate limits. It will not handle TV signals into homes or businesses nor lend itself to optical fibers on every subscriber loop, but the limits are the consciously specified system limits, not the everyday, unpredictable happenings of equipment obsolescence or parts availability.

Modularity

The perceptions listed thus far led to a system architecture of distributed subparts--each subpart stands substantially independent of the other subparts. Two important aspects in the specification of these subparts or subsystems are

1. The idea of modular independence and
2. The notion of logical interface.

By independence it is not meant that there is absolutely no relation to or connection with the other parts of the system. That would deny that there is a meaningful system. Rather it is meant that small, arbitrary, local changes in a subsystem have no consequence and no impact on other subsystems. For example, if the number of possible positions of a retarder mechanism or the wiring list for a specific terminal block is changed, those differences should cause changes only within the retarder controller itself, not in any other part of the control system. Knowledge of implementation-dependent details should be confined to the controller or zone or subsystem involved. Therefore the system and the subsystems are independent in that superficial, implementation-dependent details and changes do not propagate throughout the system.

This relates to the idea of a logical interface. Because communication to and from a subsystem, such as a retarder, is in terms of the work it does (e.g., desired exit speed, actual exit speed, weight of cut, and length of cut) rather than how it does the work (i.e., set 24 volts to terminal block pin B2-7), modular independence is supported.

These ideas are essential. If modular independence in the sense described previously is not accomplished, any hope of segregating a complex system into tractable portions is lost. The resulting system will not be easily expandable and modifiable because any change will tend to subtly propagate into hidden parts of the system, making change impracticable.

Microprocessors

One may ask why such a distributed approach to yard design was not considered previously. The answer is that the ideas of modular independence and logical information transfer are impractical unless it is possible to place substantial information-processing power into the individual subsystems and controllers. The local control of retarders, switching, and so on, requires sophisticated logic such as that associated with computers and substantial computer programs. Furthermore, the translation of information such as desired speeds and other parameters in logical form into specific electrical commands and sequences also requires processing of a complexity and degree that implies computers in some form.

Until recently providing this type of processing power in a form other than a mainframe computer was next to impossible. Today, however, distributed architecture is made feasible by microprocessor technology--the placing of computers into a dozen or so integrated circuits on a single printed circuit board.

SYSTEM OVERVIEW

With the assistance of this microprocessor technology, General Railway Signal (GRS) has developed a distributed classification yard control system. This control system parallels the level of automation desired in a yard and allows computerization of functions of the yard in phases. Self-diagnostics and user-initiated diagnostics of the system allow rapid detection and isolation of system and field failures.

This yard-control system begins with a series of modules loosely coupled together. Most modules contain an interface to field equipment as well as sufficient computing power to perform individual functions. Communication is handled through a simple interface in which information is passed from one module to another.

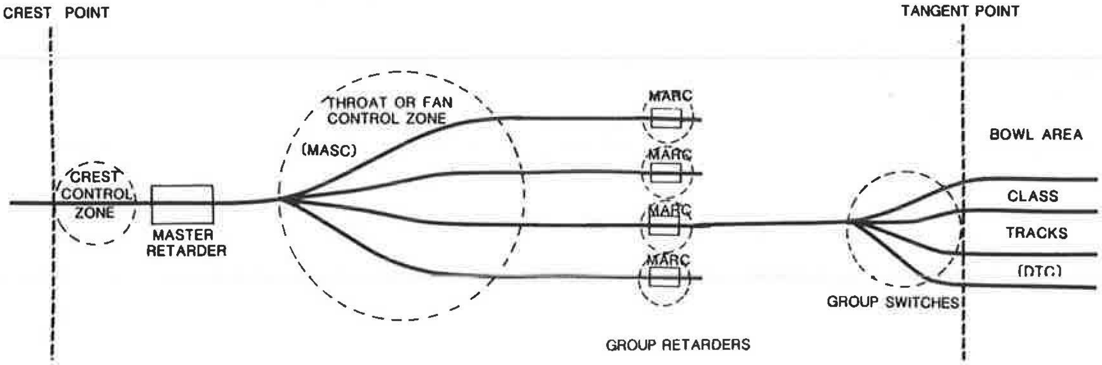
In its simplest conceptual form, a yard process-control system consists of inputs and outputs both to field devices and to the operations personnel. In the distributed classification yard-control system developed by GRS, the various control system functions are handled by separate processors. Interfaces between personnel and machines are performed by the operator communications (OPCOM) module. Field input and output (I/O) as well as the logic necessary to effect logical control are distributed into individual controllers, each capable of fully controlling one specific function in one specific place. For example, one controller is responsible for the master retarder logic, whereas another may control the group-3 switching. This configuration combines the best of both a functional organization (retarder, switching, reports, and so on) with a geographic arrangement (throat region, group region, and so on). Both complexity and cost are reduced by including only those modules needed to effect the desired control. The final logical subsystem in this concept is hump control (HCON). This module along with communications multiplexers make up the nerve center that links the various modules together.

Figure 2 shows a functional block diagram of the proposed classification yard control system. A description of the functional parts follows.

Operator Communications

OPCOM handles all commands from the operators of the

Figure 1. Track and equipment layout of a yard.



compute a target exit speed for release of the cut from the master and group retarders.

7. Retarder control: The system must provide control of retarders to release cuts at a preselected or computed exit speed. The control should be safe with minimum retarder movements.

8. Operator interface: Appropriate input and output must be provided for dialogue with the system's users.

9. Maintenance interface: Means must be provided for diagnosing system failures, changing various internal parameters, and monitoring system performance.

10. Report generation: The system must provide for hard copies of various reports of system activity.

SYSTEM REQUIREMENTS

The second step in the project was to describe characteristics needed in the new system. Basic items included expandability, maintainability, physical plant, and long system life.

Expandability

An acceptable system must be expandable in two respects. It must be easy to add more of what has already been installed, e.g., more group retarders and switching groups. That is, revision to previously installed portions of the system should be minimal, preferably only to identify the new equipment to the system.

The system must be expandable, or modifiable, with respect to alternative or new types of equipment and to functions nonexistent in the initially installed system. It should be possible to include new types of retarders, distance to couple, and enhanced operator interfaces without extensive impact on the previously installed control system.

Maintainability

Systems are often impossible to maintain to the point where a fault can typically leave competent maintenance personnel staring at the equipment in hopeless frustration. The only recourse may be to call the original designers.

For a system to be maintainable, it must be possible for a maintainer (knowledgeable about the overall functioning of the system and its basic structure) to pinpoint (in a methodical way) what is working properly and what is not. This pinpointing allows the maintainer to isolate a fault to the level of a broken wire or faulty circuit board, power supply, or relay.

Physical Plant

A minimum amount of floor space for the equipment, an uninterruptable power source (UPS), and adequate cooling and heating are required to keep the office-based portion of the control system reliably operable.

As a target, two relay racks 85 ft high by 19 ft wide should be sufficient to contain the signal-processing and information-processing portion of the control system. (This would not contain the UPS, incoming termination panel, any test panel, or power-handling relays.)

Long System Life

Obsolescence is a major risk in most systems. To protect the investment, it should be possible to

1. Replace subsystems at those times in the future when spare parts become unavailable without altering or replacing the remainder of the system and
2. Incorporate desirable or necessary enhancements into the system without major modification to the system [e.g., new types of retarders or DTC or management information systems (MIS) interface].

Furthermore, upgrades should be possible without the replacement of expensive and properly functioning parts, e.g., retarders and their controllers.

THE DISTRIBUTED SYSTEM

A number of perceptions led to the specification of a distributed control system. These perceptions included natural partitioning, expansion, system flexibility, modularity, and use of microprocessors.

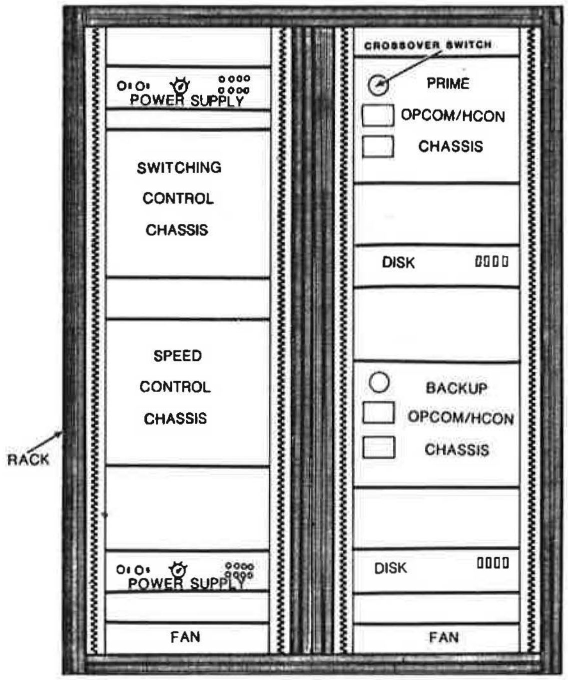
Natural Partitioning

Classification yards are naturally partitioned into clusters of equipment and geographical regions that correspond quite well to subfunctions of the yard. The characterization function (and equipment cluster) in the crest region, the retarder region, the throat switching zone, and so on, each constitutes a parcel of localized sensing or control or both sufficiently complex to warrant a dedicated controller.

Expansion

The naturally partitioned zones and subfunctions are the usual units of expansion. Adding groups or extending a limited control system to include group switching (for example) are typically required for updating or for seeking a higher degree of automation.

Figure 3. Packaging diagram.



5. As the cut leaves the control region of the yard, HCON delivers the contents of the overall cut history to OPCOM. OPCOM prepares a report for the printer.

HARDWARE DESCRIPTION

Figure 3 shows the typical rack layout of the control system parts shown in the functional diagram. Not shown are the UPS, test panel, the incoming termination panel, surge protectors, or the relays and logic that provide manual retarder override.

This portion of the control system requires less than 10 ft^2 and less than 3 kW of 115-V AC power (and consequent equipment cooling).

SYSTEM MAINTENANCE

Run-Time Diagnostics

During normal operation of the system consistency checks are performed and messages reported for abnormalities. For example, should a message arrive between subsystems that in some respect is inconsistent or unintelligible, this is reported. Should an input-output signal value be improper (e.g., a pressure grossly different from that commanded), this is reported. Should the microprocessor of a controller reset via its watchdog, a message is reported to an operator and to a report printer.

It is believed that a maintainer will be armed with information provided by these normally running diagnostics before ever approaching the system in response to a complaint.

Backup

In the area of the controllers, backup can take the form of duplication of controllers with inputs provided simultaneously to prime and backup printed circuit boards. Outputs must be switched, which might be done manually by a maintainer or automatically by the control system. Impact on system complexity and complexity of the controller programs is minimal; the transition is primarily a matter of switching messages to the alternate unit.

In the region of OPCOM and HCON, the higher-order region of the control system, it appears desirable to manually control any transition from a prime OPCOM/HCON pair to a backup. A fully automatic transition would be complex and not foolproof. If an operator cannot communicate with OPCOM or feels the sequencing of action on cuts from HCON is incorrect, he or she can simply ask the maintainer in the equipment office to switch to the backup equipment.

Logical Progression

The purpose of maintenance activity is to isolate a faulty printed circuit board, broken interconnect wires, or faulty power supply. Maintenance activity can also circumscribe a control program error (which should be rare) in which yard operation may be resumed through a manual reset of a processor. But for the class of problems requiring immediate repair, a fault is sought in the hardware.

If a problem is known at the onset to be specific to a controller (for example, a retarder controller, MARC module), then the problem is already isolated to the two printed circuit boards, cabling, or field equipment associated with that retarder. Either through local attachment of a terminal with CRT and keyboard or through the maintainer's terminal, the maintainer may communicate with the controller microprocessor to obtain information on the controller and the value of field input signals and establish output values that may be checked by direct observation or electrical measurement.

If the problem has not yet been isolated, the maintainer progresses in the following fashion. First, the communication with OPCOM is checked from the maintainer's terminal. If there is no response to various requests, then the OPCOM microprocessor is faulty, the terminal is faulty, or there is a bad cable connection.

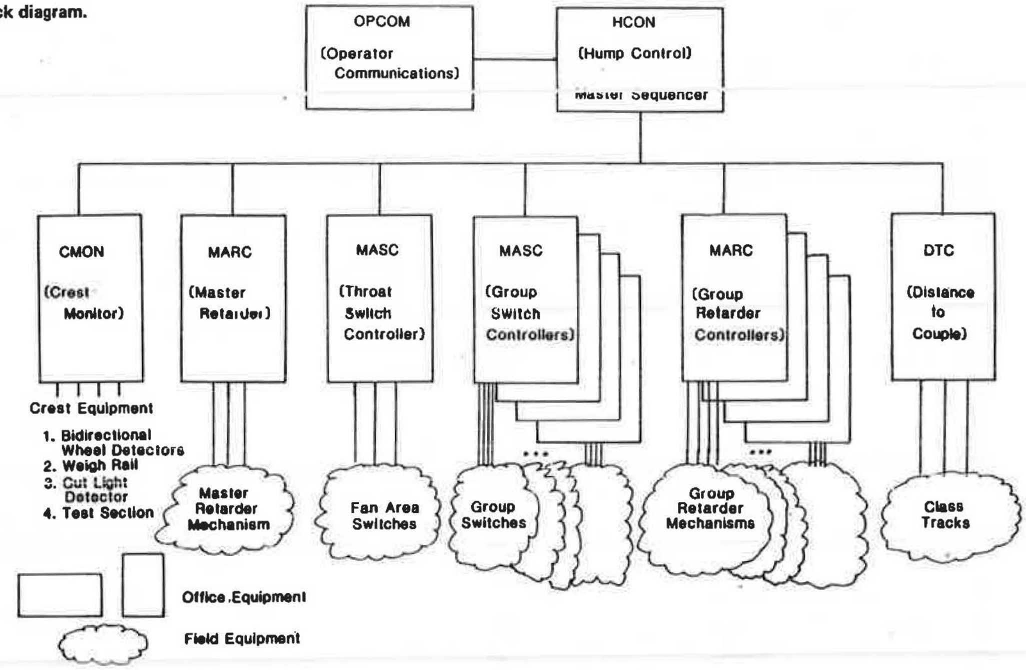
If communication with OPCOM is possible, the maintainer can interrogate HCON, again from the maintainer's terminal. Interrogation of HCON should reveal whether HCON is operable or whether a downstream subsystem is the problem. If HCON is faulty, examination of power supply voltage values and cables and swapping of circuit boards is in order. If a downstream unit cannot be accessed, the problem has been isolated to that unit.

In this system, communication with the various distributed entities is possible, both through the normal system communications means and locally through a specific plug-in point. Local processing power permits substantial, structured access.

Association of I/O Wires to Corresponding Controller

When trouble has been isolated to a specific functional region (for example, a switching zone, a MASC module), examination of signals at the module that lead to and from the field is especially easy. The maintainer does not have to work from a bulky set of diagrams to find the pertinent terminal blocks. The module is located in a clearly defined slot position in the switching controller chassis. The I/O board is immediately below the MASC processor board. The I/O connector on that I/O board is cabled directly to the corresponding plug coupler on the hinged rear panel. All signals are available at the edge connector and at the plug coupler. The same signals are brought to the same pins on all of the MASC modules and are furthermore segregated in a consistent pattern. This expedites maintenance considerably.

Figure 2. Microyard functional block diagram.



system--yardmaster, hump conductor, retarder operator, and maintainer. Depending on the degree of automation, OPCOM can be a simple control machine with speed-select dials or destination-track pushbuttons or both or, at the other extreme, a set of terminals with CRT or keyboard with full status displays and MIS connections.

Hump Control

Hump control (HCON) is a high-level master sequencer of real-time yard-control activity. As cuts enter the control region, HCON determines what subsystem handles what cut at what time. It arms the various equipment controllers with functional information concerning the approaching cut, conditions affecting control, and behavior desired. As traffic leaves a subsystem, HCON is notified, keeps track of traffic changes, and delegates control to subsequent subsystems.

HCON ensures that the cut characterization is reasonable, calculates the requested exit velocity from each retarder, and maintains a set of cut statistics regarding each cut in the system.

Crest Monitor

Crest monitor (CMON) detects new cuts coming into the control region and measures the relevant characteristics of the cut such as number of cars and axles, weight, height, and rollability.

Microprocessor-Assisted Retarder Controller

Each microprocessor-assisted retarder controller (MARC) controls a retarder mechanism to establish the desired exit speed, given the cut weight, length, and number of axles.

Microprocessor-Assisted Switch Controller

Each microprocessor-assisted switch controller (MASC) tracks the movement of cuts in its zone of the yard and positions switches to effect correct movement of cuts.

Distance to Couple

Distance to couple (DTC) is measured on each of the classification tracks through either direct electrical measurement based on shunting or car-count processing.

SYSTEM DESCRIPTION

A typical car transit in the distributed system follows a general progression, described as follows:

1. A car is identified by desired destination track before it encounters detection equipment in the crest region. In more complex yards a hump list, generated from a remote MIS data-processing facility, is transmitted to OPCOM before the train arrives at the hump. In other yards a button on a control panel is pushed by the hump conductor to distinguish destination tracks.
2. As the cut crosses the CMON bidirectional wheel detectors, HCON is notified of traffic. A sequence number is assigned to the cut and a memory block is assigned in HCON to specify its desired routing and to record its history through the control region. As the rear knuckle of the cut passes the cut light detector, CMON determines the number of cars in the cut and passes the information to HCON.
3. As the car's weight, wheelbase, and rolling resistance are measured by CMON, HCON is informed. HCON issues information to the master MARC and throat MASC to permit initial speed control and routing control.
4. Each subsystem or controller queues (saves up) information it receives from HCON pertaining to arriving traffic before its arrival. Hardware events sensed by each controller are interpreted as the movement of traffic unless faults are discerned. Cuts are handled and final reports on the cut behavior, handling by the controller, and state of controller equipment are sent to HCON as the cut leaves the control zone. Each controller purges its information about the cut after the cut has completely passed through.

SUMMARY

The design described does not purport to be the answer to all classification yard control problems. It will not fulfill the functional requirements of all classification yard installations; nevertheless, it is believed that a system could be developed from this design to economically meet the needs and requirements of many existing yard facilities. The designers of this system maintained a practical approach in hopes that modern computer technology could produce a system (while not providing the ultimate in functional capability) that could be applied in yards where existing systems have been cost prohibitive.

ACKNOWLEDGMENT

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