was improved. The phased approach to system function upgrades combined easily with the computer hardware recycling.

The phased approach minimized the negative impact of change on yard operation. Each phase evolved from the previous one, which almost led the user ahead. Major retraining of personnel was not required.

Most of the code was developed on site and was tested as developed. Some of the code, particularly that for handling exceptions, was better tested in the field than in any laboratory that could have been economically created.

The implementing team gained by direct exposure to the experts, the car retarder operators. Much of their experience was eventually translated into program refinements.

Cons

The large amount of out-of-town work contributed directly to the high personnel turnover experienced during the project. Developing the experience of the implementing team took more time than hiring a new team of experts. Out-of-pocket expenses were relatively high simply because of the implementing team's expense accounts.

An individual railroad cannot afford the overhead of a large development staff such as the signal companies possess. This tends to concentrate too much specialized information in too few hands.

Old field hardware and cables caused the use of inputs that were less than ideally located and more error prone. Eventually several had to be replaced and relocated. Some had to be enhanced by backup devices.

The lack of a central development and test facility forced some work into the field that could have been done without incurring travel.

Costs

A definite trade-off exists between the expense of keeping a team in the field and the capital costs of a central laboratory.

Control systems involve a specialized type of programming. Railroad control systems are even more specialized. Hiring or training personnel with such specialized skills is costly.

For an automatic system to work well a high degree of maintenance of facilities and equipment is required. This includes such mundane items as working rail greasers and well-maintained track grades, all of which is costly.

PRACTICAL SYSTEM LIMITS

The master and group retarder configuration is becoming ever more inconsistent now that longer cars and constant-contact side bearings make up a large percentage of the car fleet. At older yards that have tight curves in the bowl tracks this problem is becoming severe. Some measure of curve resistance is needed to reduce the inconsistency. The obvious alternative to this is tangent-point retarders.

Human factors must be carefully considered. An ill-defined approach to how the hump conductor is to relate to the system can make the job appear impossible.

Simple-looking but hard-to-achieve changes to yard layout can improve performance. For instance, having some accelerating grade through the group retarders can add to the system's recovery capability for cars that are controlled to below their target speed.

SUMMARY

Puting a computer in an old yard is not a panacea. A successful project to do this requires a strong commitment from management to that goal, particularly if jobs are to be cut off as a result of computer installation.

A computer by itself will probably help in freight claims by lessening damage, but this may slow the humping rate. A slower hump rate may not affect the number of cars per day over the hump, but less hump-engine time is available for duties other than hump activities.

Maintenance costs are higher than in a manual yard because of a larger array of equipment to be maintained. If the yard is adequately configured, a computerized master and group retarder scheme will reduce damage, labor costs, and misroutes. Without a good yard layout, installing a computer will probably be no help in reducing damage claims.

The VR-IV Retarder Control System

DAVID C. CONWAY

A system for controlling the speed of freight cars coming out of car retarders in classification yards is described. The key element of the VR-IV system is the use of an acceleration servo to cause cars to decelerate at a constant rate and achieve the proper exit speed just as they leave the retarder. This is in contrast to the velocity servo used in earlier systems. With a microprocessor, the VR-IV system continuously repeats the computation of deceleration that will produce the desired exit speed; then it operates the compressed-air application or exhaust valves to produce the proper air pressure in the retarder cylinders.

In this paper a car retarder speed-control system is described that was designed to cause cars to decelerate uniformly throughout the entire length of the retarder. This is a desirable feature for several reasons. First it distributes the wear evenly throughout the retarder instead of causing the work and the wear to occur at the front end. Second it allows cars to maintain a higher average speed through the retarder, which increases the production rate or throughput. And third, in the case of electropneumatic retarders, it produces a substantial savings in compressed air by maintaining a relatively constant air pressure for any given weight of car.

OVERALL YARD CONCEPT

Before the Union Switch and Signal Company (US&S)

VR-IV retarder speed-control system is discussed, brief mention will be made of the overall yard concept from the point of view of a classification yard systems engineer.

Fundamentally, in a modern railroad terminal incoming trains must be disassembled and then reassembled into outgoing trains. The classification yard is the key element in this process.

Because virtually all of the traffic handled by a terminal must pass through the classification yard, it is vital that this operation be performed as smoothly and as quickly as possible, lest the yard become the bottleneck of the terminal.

The classification yard allows free-rolling cars to accelerate to a reasonable speed, pass through the switching area, and then proceed along a bowl track to a safe coupling with a previously humped car on that particular track.

Normally the crest of the hump is made high enough to provide most cars with sufficient speed to roll to coupling. Nevertheless, easily rolling cars would attain higher speeds than poor rollers. With no intervention, good rollers would overtake poor rollers and be routed to the wrong track. To prevent this, car retarders are placed along the route between the crest and the entrance to the bowl track to control the speed of the cars. The more retarders along the route, the better the separation between cars can be maintained and the faster the train can be classified or humped. Retarders, however, cost money and placement is an important factor in the design of hump yards. The most popular yard configuration has master and group retarders. However, when high hump rates are desired, retarders are required at the tangent point of each track. Tangent-point retarders allow speeds through the last switch area to be higher, thus reducing the likelihood that cars will catch up to each other.

RETARDER SYSTEMS

There are a wide variety of retarder configurations and control devices. US&S uses pneumatic retarders with solenoid-controlled pilot operator valves. These components were chosen because they are clean, respond quickly to control commands, and provide unlimited selection of control pressures up to the system line pressure. Also, US&S classification yard switch machines are pneumatically operated, so one compressor system can operate the whole yard.

Retarder control schemes range from simple manual control by a lever on a retarder operator's console to highly sophisticated automatic control like the VR-IV system.

With manual control a retarder operator uses his own judgment to select a suitable pressure that will not squeeze the wheels out of the retarder. He has only a four-position lever to select retarder pressures. He must be aware of the bowl track to which the car is assigned, and he must presume a proper exit speed for the car. Then he must open the retarder at just the proper time to allow the car to maintain that speed. Obviously, the whole operation requires the undivided attention of an experienced operator.

With automatic control, a weigh rail, radar, and electronic hardware assume many of the retarder operator's decisions. A weigh rail ahead of the master retarder measures the weight of each car and classifies it in one of four categories: light, medium, heavy, or extra heavy. Maximum retarder pressure limits are set according to these categories. Doppler radar monitors the car's speed while the car passes through the retarder. The retarder operator must still be aware of the destination of the car so that he can select a suitable retarder exit speed. The selection is made by turning a dial on the retarder control console to the desired exit speed.

In more modern yards where process-control (PC) computers are used, the retarder operator is relieved of the task of deciding what the proper speed should be. An algorithm based on the formula for conservation of energy computes the optimum exit speed by using electronically determined space available on the destination track and a rolling-resistance measurement for the car that is determined by the PC computer.

The rolling-resistance measurement is used to predict how much energy a car will lose after it leaves the last retarder and while it is traveling through the curves of the switching area and along the tangent bowl track to the coupling point. The purpose of the algorithm is to determine the amount of energy that is required to overcome these losses and to cause the car to couple at an acceptable speed. The total energy is then converted to group retarder desired exit speed.

Before use of the VR-IV the proper exit speed was achieved by electronic hardware in the configuration of a velocity servo. The role of the velocity servo was simply to reduce the speed error to zero somewhere along the retarder and then to maintain that condition until the car left the retarder. In the velocity servo the actual speed is compared with the selected speed and the difference, or speed error, then controls the air application and exhaust valves accordingly. In this type of control system the entering end of the retarder does most of the work and sustains most of the wear.

VR-IV SYSTEM

Rather than attack the speed error as the velocity servo does, the VR-IV focuses on deceleration, or the rate of change of velocity, as the car passes through the retarder. The objective of the VR-IV is to determine the proper deceleration and then to control the car's actual deceleration to produce the desired exit speed just as the car's last axle leaves the retarder. The entire available length of the retarder is used in this computation. The actual deceleration of the car is derived from the radar Doppler signal. The acceleration servo adjusts retarder pressure to make the actual deceleration equal to the desired deceleration. When the difference is zero, the car leaves the retarder; when it is not zero, the system increases or decreases pressure to make it zero. The VR-IV does not stop there. The desired deceleration is computed continually as the car passes through the retarder. For each 1 1/8 in. of progress through the retarder, or every other Doppler pulse, a new computation is made. This allows the pressure, which is initially set to a nominal value, to be adjusted continually. Ideally, once the proper deceleration is achieved, no further changes in pressure should be needed.

The system responds automatically to car wheels with varying coefficients of friction. When a car has wheels contaminated with grease or other lubricating substance, the retarder pressure is allowed to build up to a higher level than normal. Then when the contaminant wears or burns off and deceleration increases, the pressure is adjusted accordingly. Thus with the VR-IV some cars are controlled properly that with other control systems may have left the retarder at too high a speed. This flexibility of control pressures and the continually updated computations of desired deceleration provide accurate control of exit speed.

The VR-IV achieves a new level in the status of retarder speed control, and new electronic hardware was required to accomplish it. An additional radar unit at each master and group retarder was required in order to be certain that a good Doppler signal was available regardless of the car's position in the retarder.

A new radar Doppler signal processor was developed. The circuit is called a hole filler, and it does just that by supplying pulses that are missing in the Doppler signal. Because of reflected radar energy from various parts of the car, some Doppler pulses are cancelled out and some extra pulses occur. These phenomena are called dropout and multipathing, respectively, and the hole filler overcomes their effect, providing a much smoother and more accurate signal that represents the actual velocity of the car.

A microprocessor unit was designed into the VR-IV system for executive control of the many modes of operation and decision tasks required. The microprocessor selects the proper control valves and air-pressure limits for the system. It also enables system control of the valves through acceleration-mode logic or velocity-mode logic. If a situation occurs in which two cuts catch up to each other, the microprocessor takes appropriate action to provide the best control of both cuts in the retarder. It selects the entering-end radar or leaving-end radar based on the position of the car in the retarder, and when no car is present, it initiates a system reset and self-test.

The microprocessor monitors the failure status of the VR-IV subsystems. It also receives information on each cut from the PC computer. By using all of this information, it determines and enables the appropriate mode of operation. A watchdog timer monitors the microprocessor to detect its ability to complete its scan; if it cannot, the timer takes appropriate action to place the system in a back-up mode.

A complete new retarder air-pressure measurement and control system was also developed by which a pressure transducer converts retarder air manifold pressure to an analog signal proportional to that pressure. This signal is compared with the analog value of the desired pressure, and the retarder pressure is adjusted to match. Pressures can be selected in this manner, or they can be raised and lowered on demand from the acceleration servo.

A system for tracking a car through the retarder was also developed. By using a wheel detector at the entrance end of the retarder to count axles in and a wheel detector at the exit end to count axles out, a running count of the number of axles in the retarder can be maintained. This is necessary to determine the amount of deceleration available at any moment.

Many parameters must come together in the computation of desired deceleration. The PC computer passes the number of axles in each cut of cars to the VR-IV system. Then the number of axles multiplied by the length of the retarder is a measure of the total amount of the retardation available. Because the reception of each Doppler pulse indicates progress of about 9/16 in. through the retarder, the total length of retarder available is diminished by 9/16 in. multiplied by the number of axles in the retarder at that particular time. Also, to determine the desired deceleration, the difference between the actual velocity squared and the desired exit velocity squared must be calculated and then divided by the remaining available retarder length. The result is the desired deceleration and it is computed over and over again every 1 1/8 in. through the retarder.

Another circuit compares this desired deceleration with the actual deceleration to produce the deceleration error. The sign of the error signal indicates whether the pressure should be increased or decreased. The deceleration error signal pulse width modulates the control commands to the air application and exhaust values to reduce the possibility of overcontrol. This allows more precise control of deceleration and thereby produces a high degree of accuracy in speed control.

In conclusion, even though the VR-IV retarder control system is somewhat more complex than earlier systems, the benefits are also greater.

Compared with the earlier velocity servo systems, lower preset pressures are used for each weight category, and the pressure increases only to the extent required. This means that the air volume used is reduced and the air compressor plant size can be reduced significantly.

Because the retarder air pressure is made only as high as it needs to be to cause the desired deceleration, pressures will generally be lower and more uniform than in earlier systems. This reduces stresses at the entering end of the retarder and distributes work and wear more evenly along its length. It also reduces the frequency of brakeshoe replacement.

Increased retarder pressure limits increase the retarder effectiveness for light, medium, and heavy cars with low coefficients of friction.

When the whole retarder is used to achieve the desired exit speed, the average speed through the retarder is higher; therefore less time is spent in the retarder. This allows cars to follow more closely and allows throughput to be higher.

Finally better accuracy in the control of exit speeds means a better chance to get good coupling speeds in the bowl tracks. In other words, the VR-IV can improve the effectiveness of the classification yard, which will improve the efficiency of the terminal.

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