Railroad Incorporates New, Fail-Safe Technology to Replace Aging Controls

Allen-Bradley's GuardPLC™ ensures safety and helps reduce maintenance of drawbridge by 50 percent

Paducah & Louisville's Rockport drawbridge, spanning 520 feet over the Green River, was built in 1931 and is equipped with a bascule-type lift.

Ignoring the popular adage "if it ain't broke – don't fix it," railway companies are looking to replace aging controls with more reliable, intelligent technology. Why? "Because unlike traditional manufacturing processes, railroad accidents cause more than just downtime and loss of product," explains Dwayne Edwards, general supervisor of signals and structures at Paducah & Louisville (P&L) Railway. "Derailments, combined with the hazardous contents and the sheer weight of freight cars, can quickly lead to casualties, evacuations and a very unforgiving public."

Railway companies taking the proactive approach to control technology literally have one eye on the tracks, and one eye on the transportation market. With more than 40 percent of U.S. freight moved by rail, the railroad industry's market share currently surpasses all other single modes of transportation. The railroad's lead on trucks, planes and barges is attributed to providing customers with high quality service at the lowest possible price. But while the more than 550 U.S. freight railways have primarily relied on good ole' elbow grease to maintain this position, companies such as the P&L Railway are now augmenting hard work with new technology.

With 281 miles of main line used to transport more than 15 million tons of coal, chemicals and supplies annually, P&L is recognized as one of the premier regional railroads in the United States. Its tracks in western Kentucky are strategically located to provide customers access to both the inland waterway system and five of the eight national or "Class I" railroads.

Beyond miles of track and yearly volume, P&L is most proud of its exceptional safety record. In fact, P&L has received accolades from the prestigious E.H. Harriman Memorial Institute and other industry groups for its safety performance.

This is no small feat when taking into account that the entire rail industry is hampered by a lack of capital for ongoing improvements. In terms of profitability, the rail industry averages a seven percent rate of return on net investment.

"Our approach rests on the fact that to have a safe operation, we need safety oriented employees that use their heads instead of their grunt," Edwards says. "We empower our employees to always take the safe course of action, look for and recommend ways to ensure personal safety for themselves, fellow employees, and operational safety."

Working on the Railroad

The most recent safety initiative at P&L involved auditing and improving the technology used on one of its signaling systems. Much like a typical road, a freight train's movement through an intersection is governed by green, yellow and red signals. These indicators control train movement through an integrated series of signal blocks. Each block consists of ten or more miles of track, and train crews carefully watch signaling systems located at the entrance and intermittently within the block to know what pitfalls, if any, lie ahead. Some of the most common roles of a signaling system are to alert trains to the presence of other trains, broken rails and improperly functioning switches within the block.

Advance warning is especially important when it comes to rail transportation due to the time it takes trains to stop. For example, a train traveling 35 miles an hour requires more than a mile to come to a complete halt. Any obstruction on the track short of this distance risks running head-on with the braking locomotive. And since most trains travel faster than 35 miles an hour and have loaded cars weighing more than 100 tons each, the collateral damage of such a collision can be devastating.

Chugging Along With Old Technology

While the P&L signaling systems haven't been a problem to-date, the company chose to focus on them due to their aging control technology, and the phenomenal risks associated with a potential failure.

"Some of the control technology used in signaling systems is up to 60 years old," said Edwards. "There comes a point in time when you need to replace this technology even though it is properly functioning."

P&L was especially interested in incorporating technology that was certified fail-safe and met the new guidelines set forth in the International Electro-Technical Commission (IEC) 61508 standard for functional safety of electrical, electronic, programmable electronic safety systems. "The safety guidelines and product testing procedures are much more advanced than in the past, and the resulting quality assurance is priceless in an industry like ours," Edwards explains. P&L was also attracted to the possibility of reducing ongoing maintenance.

The Allen-Bradley GuardPLC, which is housed in a 8X10' concrete enclosure monitors the Rockport bridge's interlocks, span locks and rail lifts to ensure fail-safe operation.

Intersections and other high-traffic sections of a railroad are required by law to have a signaling systems. The green, yellow, and red signals on P&L's Rockport drawbridge can alert trains to the presence of other trains or boats, broken rails and improperly functioning switches.

Getting the Green-Light for a New Solution

"We calculated that by replacing some of the relays and other mechanical components, we could reduce maintenance of a signaling system by as much as 50 percent," says Edwards. This calculation proved correct when P&L updated the signaling system on one of its drawbridges.

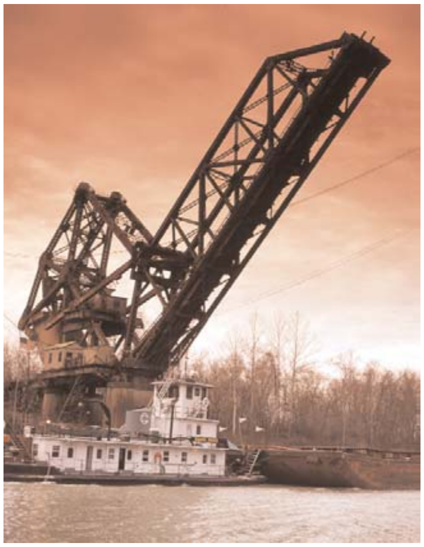
As the name implies, a drawbridge is 'drawn' to allow safe passage of boats and lowered to allow safe passage of trains. And like other signaling systems, drawbridge equipment has zero tolerance to failure. Even a single short-circuit can lead to a barge colliding with a half-raised bridge … or a train moving forward before all bridge interlocks are in place. Such nightmare scenarios drove P&L to update its Rockport drawbridge, spanning 520 feet over Kentucky's Green River.
The drawbridge was built in 1931 and is equipped with a bascule-type lift, which lifts up with the help of a hinge-like component on one end of the bridge span. On a daily basis, 8 to 10 trains and an equal number of watercraft encounter this particular bridge. The P&L train dispatcher, located 120 miles away, in the city of Paducah, Ky. remotely controls the bridge's position and monitors its operational status.

For example, a barge traveling down the Green River contacts the train dispatcher via radio and requests permission to pass. If there are no trains within the block (Beaver Dam, Ky. to Central City, Ky.), the train dispatcher triggers a raise request, which the signal system recognizes and the train control signals display a red "stop" signal. After a preset time the bridge will begin to lift and when fully raised, a green "proceed" signal will be displayed for river traffic. The barge continues its course down the river and radios a message to the dispatcher after clearing the bridge. The train dispatcher will then request the bridge down, and the river traffic signal will display a red "stop" signal. When the bridge assumes the down position, a series of system checks begin. If all checks are verified complete and in the proper sequence, the train control signal will display a green "proceed" signal. Any interruption or out-of-order event results in an immediate red "stop" signal for all incoming traffic and a "trouble call" to a maintenance engineer.

The behind-the-scenes technology of the old system included:

- 48 relays
- Conventional DC track circuits
- An aerial cable running from pole lines situated along the bridge
- A 110 volt DC power switch machine
- Linkage system consisting of steel rods, joints, plates and bars

Here's how the solution worked: Conventional DC circuits sent current for signal control to the relays, circuit



The Allen-Bradley GuardPLC 1200 from Rockwell Automation is a fail-safe programmable controllers used to ensure the accurate raising and lowering of the drawbridge.

controllers and switch machine situated along the bridge by means of the aerial cable. The relays monitored the fourteen bridge interlocks or "safety checks" and worked with the complex switch machine to drive the rail locks. Interlocks, such as those monitoring the span-lock or lift-rail surface position, were crucial to ensuring zero failure. The lift-rail surface position, for instance, ensured that the running surface of a rail was within a 3/8-inch margin, indicating that the bridge was in the accurate position after being lowered. Unless all interlocks were in place, the watercraft or train could not receive a green "proceed" signal.

A Solution From the Wrong Side of the tracks

From a maintenance standpoint, the drawbridge's relay-intensive, mechanical solution required several engineers to spend two days a month at the bridge to perform general maintenance tasks, in addition to the scheduled weekly, monthly and bi-annual safety checks. A majority of time during these site visits was spent conducting tests mandated by the Federal Railroad Administration, conducting additional safety checks unique to P&L, and lubricating the more than 60 mechanical pivot points on the bridge.

When P&L looked closely at the drawbridge solution, there were numerous problems the company needed to address. First, the relays – being mechanical devices – required a significant amount of attention and, with moving parts, were prone to wear and tear. The pole lines used to carry the current for signal control dated back to the telegraph, indicating that the structural integrity of the poles was questionable. Also, the signal provided by the conventional DC track circuits didn't carry well, which could easily result in a short circuit. Overriding all of these problems was the fact that there was no documented safety rating on any of the hardware used, leaving P&L vulnerable in the event of an accident.

To address these inadequacies, P&L worked closely with Interrail Signal, Inc. of Jacksonville, Florida, a systems integrator that focuses on improving the safety and reliability of railroad signal systems. The new solution designed by Interrail included:

- An Allen-Bradley GuardPLC 1200 controller
- 6 relays
- Four non-ferris (NF) proximity sensors
- Coded electronic track circuits

The backbone of P&L's new solution is the Allen-Bradley GuardPLC 1200 from Rockwell Automation. A certified, fail-safe programmable controller, the GuardPLC is designed to monitor the bridge sequence and all of the interlocks, span locks and lift rails to ensure the accurate raising and lowering of the drawbridge. On the bridge's signaling system, the GuardPLC monitors the following interlocks and proximity sensors:

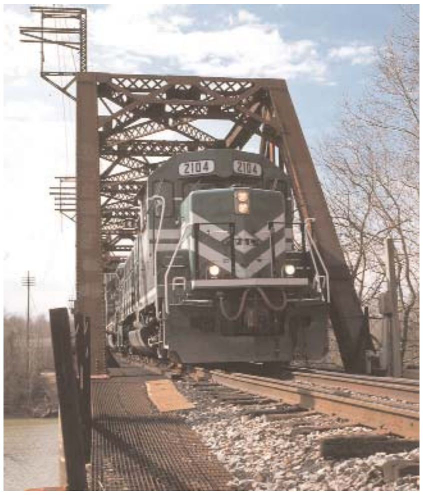
- East span lock (proximity sensor)
- West span lock (proximity sensor)
- East lift rail (proximity sensor)
- West lift rail (proximity sensor)
- Span lock repeater relay
- Lift rail repeater relay
- Bridge down check relay
- Lower bridge relay
- Raise bridge relay
- Raise bridge repeater relay
- Bridge raise-lower request relay
- Bridge up relay
- Bridge down relay
- One block indication repeater relay
- Sixteen block indication repeater relay
- North bridge track relay
- South bridge track relay
- System down relay

Chart 1	
Safety Integrity Level (SIL)	**Low Demand Mode of Operation (Average probability of failure to perform its design function on demand)**
4	$\geq 10^{-5}$ to $<10^{-4}$
3	$\geq 10^{-4}$ to $<10^{-3}$
2	$\geq 10^{-3}$ to $<10^{-2}$
1	$\geq 10^{-2}$ to $<10^{-1}$
Chart 2	
Safety Integrity Level (SIL)	**High Demand of Continuous Mode of Operation (Probability of dangerous failure per hour)**
4	$\geq 10^{-9}$ to $<10^{-8}$
3	$\geq 10^{-8}$ to $<10^{-7}$
2	$\geq 10^{-7}$ to $<10^{-6}$
1	$\geq 10^{-6}$ to $<10^{-5}$

By replacing the switch machine, linking system and 30 relays with the PLC-based system, P&L is left with far fewer mechanical components to maintain. And as a result, the company can now eliminate four days of maintenance monthly.

A Certified Safe Engine

The single most important feature of the PLC is its fail-safe components. The GuardPLC uses redundant CPUs in a single PLC controller body. Each of the logic circuits within the controller – supporting digital and analog inputs, outputs, timers, and counters – contain several checkpoints. If a failure is monitored, the PLC is designed to conduct an orderly equipment shutdown.
Since the highest safety integrity level (SIL) that can be claimed for the entire signaling system is limited by the fault tolerance of its subsystems, the certification of every component is critical.



The most recent safety initiative at Paducah & Louisville Railway involved improving the technology on its signaling systems. The system used on the Rockport drawbridge safely governs the movement of freight trains.

IEC 61508 provides four safety integrity levels. The top-most level (SIL 4) is applied to equipment traditionally used on aircraft and in nuclear power plants. The GuardPLC 1200 is certified at SIL 3, which is the safety apex for the railroad industry. IEC 61508 dictates that SILs are determined by two operating modes: the average probability of the equipment to fail its assigned function on demand (see Chart 1), and the probability of dangerous failure per hour of operation in high-demand or continuous mode of operation (see Chart 2).

"Our new hardware cost ten percent of what we would have paid to replace the switching machine, linking system and other devices previously used on the bridge."

In addition to maintaining a safe state of continued operation, the GuardPLC 1200 provides a scalable safety control system that is easily programmed with the RSLogix Guard programming and configuration software. Glen Tyson, an Allen-Bradley distributor working for Englewood Electrical Supply, helped create the sequence for P&L. As a PLC specialist, he was able to quickly create the program taking advantage of the built-in and user-defined function blocks within the RSLogix Guard software package.

As an example, the PLC programming sequence for raising the bridge looked like the following:

- Inputs 8 and 12 low; Outputs 1 and 2 high
- Inputs 7 and 10 low; Outputs 1 and 2 high
- Inputs 1, 2, 5 and 9 low; Output 1 low and 2 high
- Inputs 3, 4 and 6 low; Outputs 1 and 2 low

Glen also designed an input simulator to test the accuracy of the GuardPLC sequence before it was installed. "This was critical because any downtime after the GuardPLC went online would cause extensive delays for trains and boats," said Jim Kelley, president, Interrail Signal. "The simulation gave us the assurance we needed that the controller would perform as expected."

The Safety Caboose

In addition to the safety PLC, P&L replaced the conventional DC track circuits and aerial cable with coded electronic track circuits that send pulses in different code rates along the rail. Each code rate represents a unique signal color or message to the receiving unit. The coded electronic track provides state-of-the-art signaling capabilities, reducing the risk of having relays short-circuit. And non-ferris proximity sensors, which are capable of differentiating between the steel tracks and their stainless steel targets, are used to indicate the position of the bridge's span locks and lift rails. This ensures that locks and rails are in their proper position.

In addition to reducing maintenance by 50 percent, the GuardPLC and proximity sensors helped P&L eliminate a lot of the mechanical components that are costly to replace. "Our new hardware cost ten percent of what we would have paid to replace the switching machine, linking system and other devices previously used on the bridge. But saving hardware cost was not one of our primary goals going into this," said Edwards. "Above all, we now have a more reliable, streamlined operation."