Condition Based Monitoring for Mainline Power Switch and Interlocking

Author:

Joe Denny
RailComm LLC
1387 Fairport Road, Fairport NY 14450
(585) 598-4793
jdenny@railcomm.com

Co-Authors:

Paola Realpozo
RailComm LLC
1387 Fairport Road, Fairport NY 14450
(585) 598-4808
prealpozo@railcomm.com

Greg Fogarty
RailComm LLC
1387 Fairport Road, Fairport NY 14450
(585) 598-4799
gfogarty@railcomm.com
ABSTRACT

Many railroads identify power switch machine failure on the mainline to be one of the largest causes of train delay. When a switch machine fails, it is possible for multiple trains on a route to be delayed, which can lead to millions of dollars of annual train delay costs. One reason for switch machine failure is the introduction of excessive machine motor currents that can cause motor failure. The excessive currents can be caused by multiple sources including worn motor brushes, poor machine lubrication, obstructions in the track work that bind the switch point movement, and other factors. Railroads currently do not have an effective way to predict a power switch machine failure by analyzing the actual operating condition of the switch motor. Preventive maintenance is the only effective defense in combating premature switch failure, and this is performed based on a predefined period of time. With effective switch machine monitoring, it would be possible to convert maintenance from schedule-based to condition-based, which is to deploy maintenance forces based on the criticality of a failing switch. This approach will result in maintenance cost savings and is referred to as Condition Based Maintenance.

Railroad operators worldwide are evaluating the possibility of measuring motor currents on power switches in real-time. By monitoring the electrical load drawn by the switch machine motor through the course of the throw, it is possible to compare against a normal operating baseline to detect abnormal current draw or deterioration, before a failure occurs. Our paper will discuss the results of the evaluation of real-time monitoring of switch motor currents.
INTRODUCTION

Railways world-wide are striving to achieve efficient service levels by adhering to train movement plans even with increasing pressure to reduce operating costs and improve safety. Scheduled train movement plans become reactive and ad-hoc when service disruptions emerge and these irregularities must be handled and solved as quickly as possible. This requires a dispersed and qualified maintenance workforce to provide rapid response to work around the disruption and eventually address the issue causing the disruption. One cause of service disruption on railways today is due to electrical or mechanical failure at a signaled interlocking. A failure at the interlocking can result in train delays cascading from one to several trains depending on the density of traffic and the interlocking down time. There is a myriad of potential causes for these failures including track circuit failure, power switch machine failure, mechanical alignment failure, switch obstructions, primary/secondary power failures and so on. Points are amongst the last remaining “fail hard” elements of the system railway. There are situations where failure of an individual point can cause a total system shutdown with potentially very high costs, both in terms of operational difficulties and consequential costs. (Garcia, et al., 2007).

Different motivating factors such as safety concerns related to train accidents and on-site inspections, costly service disruptions, and having more affordable technology available have induced railroads to begin investing in interlocking monitoring solutions.
Interlocking monitoring devices communicate real-time operational data to a central support facility and provide primary remote support to various monitored components across the railway infrastructure. Utilizing constant monitoring of critical rail infrastructure coupled with communication of near-term failure alerts provides these railroads operational and cost benefits far exceeding today’s schedule-based maintenance philosophy. Condition-based maintenance is a data-driven philosophy that produces actionable information regarding the health of the railroad infrastructure.

**Schedule-based Maintenance Activity**

Today most railroads rely on an expansive, highly trained team of geographically dispersed signal maintainers to test and maintain signal interlockings, grade crossings, and defect detectors across the rail network. Because of safety regulations, testing activities are planned around a schedule, where a battery of prescribed tests are required to be performed at a specific location at fixed intervals. Track and signal maintenance personnel shall jointly perform a quarterly (90 days) inspection of all power turnouts and derails (Metrolink, 2009). The tests produce binary results that generate a compliant or a non-compliant condition. If the test generates a non-compliant condition, maintenance is performed to bring the test into compliance.

While the methodology of schedule-based testing is certainly legitimate and addresses the intent of the governing federal regulations, progressive railroads today are questioning if the information generated from the periodic testing regime is adequate to address root cause analysis of infrastructure failures causing disruptive train delays.
It is becoming more widely recognized that through schedule-based maintenance there is not much more that can be learned to address root cause of test non-compliance. Decades of testing results have been analyzed over time, and corresponding improvements in operation have largely been realized. Realizing the data generated from periodic testing is just a brief snapshot of the actual condition of the device/location under test, railway operators worldwide are beginning to explore the potential of real-time and continuous data collection, analysis, and communication of actionable information.

The prevailing thought is continuous monitoring of any critical asset will yield significant understanding (and ultimately prediction) regarding the events leading to the eventual failure of an asset. The prospect of condition-based monitoring eliminates the constraints of time, weather conditions, traffic conditions, and other aspects that may contribute to the eventual failure of the component.

**A Day in the Life of a Switch Failure – With Schedule-based Maintenance**

Typically when trains are delayed because an interlocking location does not properly respond to the control request from a central dispatcher’s command, a trouble ticket is generated and a signal maintainer is assigned the troubleshooting task. There are dozens of potential reasons why the switch did not move or lock on command, and the maintainer will eventually resolve the issue, either through a work-around or a direct fix. The maintainer will record his findings and file a report, which may be analyzed in the future.
As an illustration, a maintainer is summoned at 3AM to a cold, snow packed interlocking location because the crossover switches cannot be thrown by the central dispatcher. The maintainer is assigned to this territory, and although a relatively new employee, he knows the interlocking fairly well. In fact, three days earlier he had just performed the required maintenance regime per the schedule and all checked out ok. He did not need to make any adjustments to any signal equipment; everything checked out per the test specification.

Upon arrival, the maintainer inspects the first switch (the “A” switch) in the crossover and notices some ice buildup on the points. The maintainer will spend some time scraping the points, freeing them from the ice. At this point, the maintainer may feel the switch is free and the crossover can now be controlled. He will walk to the signal hut and control the crossover from the local control panel (assuming he has already received clearance from the dispatcher to enter the local control mode). Still the crossover does not line. The maintainer will then walk to the second switch, the “B” switch, in the crossover configuration and clear ice from its points. Again, he will walk back to the signal hut and attempt to control the crossover. Still no response. So now that the obvious fix has been eliminated, the maintainer must perform some serious troubleshooting. He recalls the track department was out last season to work on a track alignment issue that the signal department had theorized was causing intermittent switch failures. This particular location has been having intermittent problems for years, and it has become nothing but a finger pointing exercise between the maintenance of way (MOW) department and the signal department. The maintainer returns to the “A” switch in the crossover and does a complete visual inspection. He then opens up the
machine and again inspects, makes some voltage measurements, and can’t find anything wrong. Before he closes up the machine, he decides to perform a similar inspection on the “B” machine in the crossover. Almost immediately he notices the throw rod is solidly obstructed by the tie. Somehow the tie had shifted and pinched tight the throw rod. The maintainer can’t free the rod from the tie and requests MOW support. Once MOW arrives the problem is quickly resolved. This problem caused multiple trains to be delayed and cost the railroad thousands of dollars. Some trains had to be re-crewed. A priority train was delayed for hours and subsequent penalties were assessed by the railroad’s customer. But that’s railroading and the not so accepted norm. This particular incident was eventually charged to the transportation department. It turns out dragging equipment from a failed securement was the likely culprit responsible for hooking then dragging the tie out of place. This occurred more than 36 hours prior to the reported switch failure. Though the switch operated “properly” for several more throws, it eventually embedded the basket of the throw rod solidly into the loosened tie and seized there.

**Condition Based Monitoring**

The key to fully understanding incipient failures in the infrastructure of the rail network is to analyze the conditions under which each asset operates. This must be accomplished continuously, in real time. We must understand the accumulated effects of temperature, humidity, wind, ice/snow build up on the proper operation of the equipment. How do climatic conditions affect the operational lifetime of assets, including effects from landslides, lightning strikes, earthquakes, floods, fires? How do train length, weight and speed affect the performance? What are the maintenance records associated with each
asset; what adjustments have been made? What other factors contribute to the eventual failure of the infrastructure?

Additionally, we must understand and analyze how the specific assets, such as power switch machines, operate and how the above mentioned external conditions impact the operation of the asset. It is critical to break down the steps that are involved in the operation of a machine, from activation to unlocking to driving to locking. The causes of failure will typically be revealed in increased operating time, load and current (Zhou et al., 2002). By understanding the impact of external effects on specific steps of the operation of an asset, analysis can be performed and each step is parameterized by a reduced number of variables, enhancing a fault detection method.

The promise of Condition Based Monitoring is to eventually answer all of these questions over time. By equipping interlockings with real-time data recorders, continuously collecting a rich set of operating data from various aspects of the interlocking operation, and storing and analyzing this data over time, it is possible to begin to develop trends that can predict future performance behavior. To be sure, it also has the potential for overwhelming the railroad’s ability to collect and analyze the data, let alone to set the proper criteria required for automatic alarm generation.

RailComm is focused on developing actionable information from the data collected from “connected components”. This is indeed a massive undertaking and to succeed will require cooperation from regulatory entities, suppliers of monitoring and sensing products, data scientists from the world’s universities, and the railroads themselves.
We have installed a small population of interlocking loggers on one Class 1 railroad and have begun analyzing data collected from over 20 switch locations, most of them in crossover configurations. The results to date have been promising, and from the collected information we have begun to invest in developing the data analytics required to properly analyze the data and uncover trends in performance.

The next step in our research is to produce actionable information from the collected/analyzed data streams to set alarm notification thresholds that can be used to deploy maintainers based on the measured real-time conditions at any of the monitored interlocking locations. It is critical we do not produce false alarms, needlessly deploying a maintainer due to a data measurement that is not indicating an impending failure. This presents a certain Catch-22 situation. How can a railroad operator be confident a failure is about to occur?

As a hypothesis, it would seem obvious that collecting operational data from all interlocking locations would provide the potential for greater understanding of failure modes at interlocking locations. On the surface this is hard to dispute. But is it worth a significant investment to prove this hypothesis? Are there proven methods for setting up a Design of Experiments (DOE) to directly measure the potential cost savings, and therefore return on investment (ROI), prior to committing funding for large scale data collection?

In many European countries, adhering to train schedules is critical as the operating railroads are primarily transporting people (Pro-Rail Alliance, 2008 and IRG-Rail, 2013). Remote condition monitoring technology has been applied to thousands of interlocking
locations, as well as grade crossings, overhead catenary systems, and other systems that must be in working order to move trains on time. The logger data has been hugely successful in pinpointing root cause of issues, and properly assigning the cost of the issue to the responsible party.

As we learn from the rail infrastructure maintainer groups in Europe, we understand they faced exactly this same conundrum and could not make the positive return on investment case without proving conclusively the value proposition of equipping their signal locations.

One of the methods employed to prove the ROI case has been to equip an underperforming division of the rail infrastructure with the real-time monitoring equipment. This limits the required investment to a smaller sample size and allows for the direct comparison of performance improvement from the equipped division relative to the unequipped divisions. Train delay is the common attribute measured. Since train delay data has been accumulated for years across all divisions, the relative year over year improvement of the equipped division can be calculated, and therefore drive a cost benefit ratio that can be objectively analyzed.

**A Day in the Life of a Switch Failure – After deploying Remote Condition Monitoring**

If the interlocking in the above example were equipped with a real-time logger, the railroad central network management center would have received an alert that the effected switch had a higher peak current and longer throw time due to the tie
obstruction. Even though the dispatcher has no problem throwing the switch, the maintainer will be called to inspect during his regular working hours. The maintainer would be directed to the offending switch in the crossover and will have been alerted to look for a switch obstruction. The maintainer at that point may have been able to leverage the tie in place without calling MOW. There would be no train delays due to this problem, and the maintainer would not be receiving a 3AM call the next morning to address a relatively simple issue. Train schedules will not be affected; the tactical plan is not disrupted. The priority traffic remains on schedule and the railroads' customers are delighted with the service.

This is, in fact, the promise of Condition Based Monitoring. It has the potential of solving multiple, common service disruption issues under normal circumstances.

**Measured Results – Pilot Program Experience**

**Example 1: Normal baseline operation**

Each switch location is optimized to produce a baseline waveform. This waveform should be repeatable for each maintenance cycle performed. If the maintainer measures changes to the baseline this indicates physical changes are occurring at the switch location.

The following traces indicate a normal baseline operation for this switch location. Notice the consistency in each trace, with throw times effectively equivalent and current draw relatively consistent across all throws. We expect a brief spike in current as the motor is
energized, then a smooth operation through the point transition period, with another smaller spike at the end of the throw as the points hit the stock rail and lock.

Example 2: Switch Lock Excessive Current

The inner trace represents the recorded baseline trace capture. All subsequent traces will be compared to the baseline. Notice the abrupt increase in current at the end of the throw. This indicates the points may not be locking properly and a maintainer will be alerted. The root cause of this problem is from an obstruction preventing the machine to complete the throw and lock the mechanism. This trace would not have yielded a pre-failure callout, it occurred abruptly. However, since this was a crossover switch, the
collected information would have directed the maintainer to the proper switch and indicated an obstruction was the likely cause. This would result in a rapid repair of the issue, minimizing train delays and maintainer on-site time.

Figure 2: Excessive current draw at switch locking stage

Example 3:  Increase Switch Throw Time

The blue colored inner trace is the baseline capture. In this example, we detect that throw times are far exceeding the baseline, even though the switch completes the throw and locks properly. We will issue a pre-failure callout to the maintainer to inspect this location and re-adjust the performance to baseline.
Developing the Analytics Model

Even in the early stages of piloting continuous monitoring of interlocking components, we have achieved clear success in improving support for field personnel to address failure issues. Most obvious is the clear detection of which switch in an interlocking crossover configuration is the direct cause of failure when a crossover cannot be controlled by central dispatch. We immediately contribute to the troubleshooting process by directing the signal maintainer to the correct switch causing the issue, and the likely cause of the issue. This will contribute to a direct reduction in train delays and a decrease in the on-site support time for the maintainer.

Figure 3: Increased Switch Throw Time
As we continue to develop analytics around new observed failure modes, we add to our knowledge base of the expected operation of power switch machines. Each new failure mode is an opportunity to detect, analyze, and determine pre-failure characteristics.

**CONCLUSION**

Special attention is paid to railway signaling equipment, which failure statistics have shown to be responsible for a remarkably high number of service disruptions and delays (Railtrack, 2001). Utilizing constant monitoring of assets coupled with communication of alerts provides equipped railroads operational and cost benefits far exceeding today’s schedule-based maintenance philosophy. Condition-based maintenance is a data-driven philosophy leveraging mature data communication technologies coupled with cloud computing platforms, whereby massive amounts of data can be collected, categorized, and analyzed to produce actionable information regarding the health of the railroad infrastructure. Significant cost benefits can be derived from fully equipping a railroad with real-time logging capabilities. Train delays directly attributed to interlocking failures will be minimized, and train plans and schedules can be more decisive. Best practices in terms of signal maintenance and equipment life-cycle costs can be measured and negotiated with suppliers. When interlocking components do fail without warning, substantially better tools are provided to the signal maintainer to more quickly determine failure cause. When interlocking locations are maintained, a “gold standard” of baseline performance can be demonstrated.
ACKNOWLEDGEMENTS

The authors wish to acknowledge the efforts and contributions of the team in charge of the pilot program at the customer’s location, and the contributions of their technology partners.

REFERENCES


Metrolink, Southern California Regional Rail Authority, “Track Maintenance, Right of Way and Structures, Engineering Instructions”, 2009, p. 76

Pro-Rail Alliance, 2008.