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BROKEN RAIL AND ROLLOUT DETECTION TO SUPPORT QMB OPERATIONS

SUMMARY

Transportation Technology Center, Inc. (TTCI) collaborated with a railroad advisory group to progress a track circuit concept that supports the Quasi-Moving Block (QMB) method of train control. TTCI performed proof-of-concept testing, capacity analysis, hazard analysis, and requirements development.

QMB is one of three new additional modes of train control identified as an evolution of today's Positive Train Control (PTC) – namely, Enhanced Overlay PTC (EO-PTC), QMB, and Full Moving Block (FMB).

QMB inherits the capacity benefits of EO-PTC and provides additional safety benefits compared to PTC. However, QMB remains limited by the fixed track circuit blocks and does not provide significant capacity benefits beyond EO-PTC unless supplemented by potential modifications to track circuits that, together with QMB and vital rear-of-train location (VRTL), provide further capacity benefits. TTCI researchers determined that QMB, with the next generation track circuit (NGTC) concept and VRTL, has the potential to improve capacity between that of EO-PTC and FMB in steady-state following moves.

BACKGROUND

A NGTC concept was previously developed (Kindt, Brosseau, & Polivka, 2018) to support future methods of train control, such as QMB or variants thereof. The NGTC concept is intended to be a simple, reliable, and cost-effective modification to existing track circuit technology. As shown in Figure 1, the NGTC concept detects a broken rail within an occupied block by measuring electrical current on the transmission (Tx) end. If the current in the loop is substantial, then the track circuit is clear of broken rails within that current loop. If the Tx current is near zero, then a broken rail exists. The NGTC concept combines information from the Tx current and the received signal based on transmission from the opposite end.

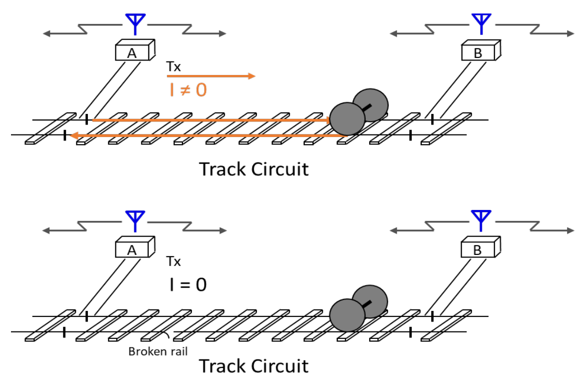

Figure 1. Next generation track circuit examples with transmission (Tx) current

Figure 2 shows the QMB architecture with NGTC and VRTL. During a PTC Exclusive Authority (PTCEA) roll up, the leading train indicates it has operational VRTL within its message to the office. The office issues a PTCEA extension to the following train, explicitly stating it can continue at maximum authorized speed (MAS) into an occupied block – but is contingent on the train receiving valid wayside status messages (WSMs) confirming NGTC is operational. Once the following train receives the NGTC-based WSM, it can then enter the occupied block at MAS and maintain MAS within the constraints of the PTC braking curve and PTCEA limit. After the following train enters the

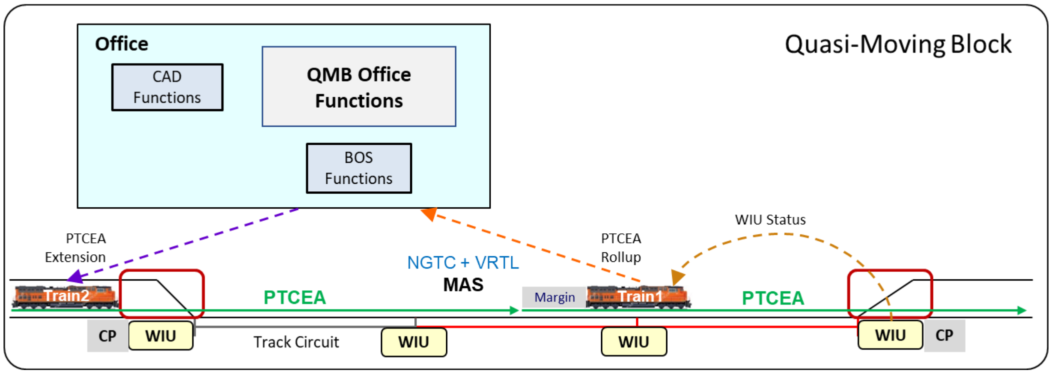

Figure 2. QMB Architecture with NGTC + VRTL

block, it is limited to restricted speed beyond the last end-of-train location reported by the leading train until the leading train clears the same block and no broken rails are detected.

OBJECTIVES

- Determine the extent to which electrical current can be used to reliably detect a broken rail (i.e., electrical open) with a shunting axle in the same track circuit under nominal circumstances.
- Identify technical challenges associated with fail-safe implementation of the NGTC conceptual design.
- Develop additional analyses and requirements documentation to advance the NGTC concept and support a future product development and evaluation phase.

METHODS

The project included meetings with an advisory group represented by key industry stakeholders to present the progress of the project, discuss and make decisions about project-related issues, and discuss the concepts of the proposed train control methods – as well as present and review results of technical analyses. TTCI completed the following tasks:

1. **Use Cases, Test Cases, and Test Plan.** Test cases were developed to determine if the NGTC concept was physically viable and identify limitations. The feasibility of the NGTC concept was evaluated by determining whether there is enough of a signal difference under the conditions that create the smallest gap between signals with and without a broken rail present.
2. **Configuration of the Testbed.** NGTC field testing was conducted on the Transit Test Track (TTT) at the Federal Railroad Administration's Transportation Technology Center (TTC), Pueblo, CO. Two signal block lengths of 12,000 and 24,000 feet were selected. The different sized signal blocks were configured by jumping around the insulated joints (IJs) at various locations.
3. **Testing.** Static and dynamic tests were conducted using the TTT testbed. For static tests, a shunt was created by an empty car to provide realistic shunting. For dynamic tests, occupancy types involved a single, four-axle locomotive, a small consist with multiple freight cars, and a hi-rail vehicle.
4. **Analysis of Results.** Results were evaluated to determine if the NGTC concept was viable at the physical level and to identify limitations.
5. **Capacity Analysis.** This analysis assessed the potential operational benefit of QMB train control with the NGTC and VRTL concept. Of particular interest was the Minimum Steady State Separation (Min

SSS) between trains in following moves, which determines boundaries where following trains would start reducing speed.

6. **Hazard Analysis.** The hazard analysis identified new and existing hazards along with potential mitigation methods. Recommended mitigations were selected and captured in the requirements development.

7. **Requirements Specification.** A requirement specification was developed for the NGTC wayside segment. The specification includes external interface, functional, performance, safety, extensibility, and Reliability, Availability, and Maintainability (RAM) requirements.

RESULTS

An electrical circuit model was created to provide a representation of what happens in an actual track circuit. The advantage of the model is the ability to easily perform a parametric study and push the limits beyond what can be done on the testbed. Selectable model inputs for parametric studies include voltage, track length, resistances, and additive Gaussian noise.

The model was validated with test data (see Figure 3). The figure is presented in terms of transmission current versus distance of shunt from the Tx source measure unit (SMU). For the test data, a multiple-car consist is moving away from the SMU at 20 mph. The test data was converted from time to distance so that it could be compared with the model. In both the model and the test data, there were small drops in the electrical current due to the resistance of the cables that were used to combine the 6,000-foot blocks together at IJ locations.

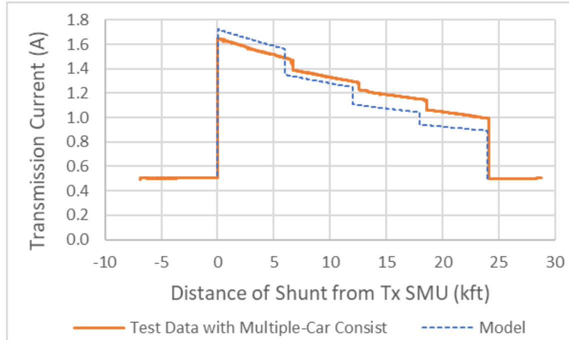

Figure 3. Test data and electrical model for 24,000-foot testbed

One of the dynamic tests is particularly relevant for evaluating the proof-of-concept condition with the smallest gap between signals with and without a broken rail present. In this test, a single, light locomotive moved away from the transmission side of the block, and a broken rail was simulated after the train passed. The broken rail was located at the farthest distance away from the transmission side at 24,000 feet. Figure 4 depicts the measured current for this test case. As shown, the smallest gap between signals with and without a broken rail was about 0.5A for the selected conditions. It was determined analytically that the gap only depends on the applied voltage and the resistance of the normal conductive path. Consequently, even though the signals with and without a broken rail present are individually impacted by the ballast resistance, the gap between them is the same, even with varying ballast conditions.

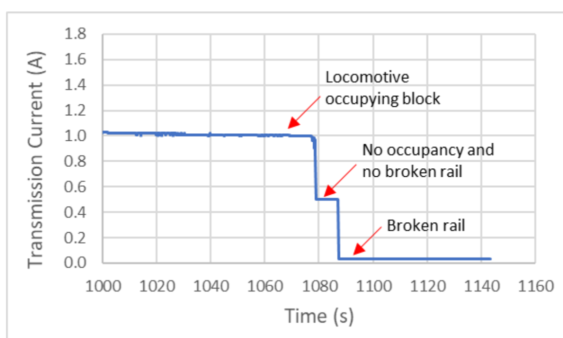

Figure 4. Single, four-axle locomotive moving from T51 to T27 at 15 mph, demonstrating the concept

CONCLUSIONS

To prove the NGTC concept, it must be demonstrated that there is enough of a difference in the measured current to distinguish when there is a rail break and when there is not. The smallest gap is created by the highest possible current level when a broken rail is present (i.e., broken rail at farthest end of track circuit) and the lowest possible current level when a broken rail is not present (i.e., unoccupied track circuit).

The results of the modeling and testing in this project demonstrated there was a sufficient gap between the signals with and without a broken rail. Therefore, the basic concept of the NGTC was proven feasible.

Capacity analysis performed on the project further shows that QMB, with the NGTC concept plus VRTL, does improve capacity in terms of minimum steady-state separation. Train separation reduction varied from 20.36 percent to 45.89 percent among different types of trains. The analysis also shows comparable train separation results between QMB with NGTC and basic QMB with half-length track circuits.

An initial qualitative hazard analysis performed on the project identified hazards and potential mitigations, which were then reflected in the NGTC design and requirements. The analysis shows that only the rollout hazard group resulted in a notable increased level of risk from current operations. However, this risk remains in the same risk category as conventional track circuits and overlay PTC. Hazards in this risk category can be acceptable with mitigation – through training, for example. As a result, the initial hazard analysis indicates that there are no unacceptable hazards associated with the concept.

FUTURE ACTION

The next step in advancing the NGTC concept is to work with the railroad industry to engage with signaling suppliers for prototype development and evaluation.

REFERENCES

Kindt, J., Brosseau, J., & Polivka, A. (2018). Next Generation Track Circuits [DOT/FRA/ORD-18/10]. Washington, DC: Federal Railroad Administration.

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