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POSITIVE TRAIN CONTROL PASSENGER BRAKING ALGORITHM ENHANCEMENT – PHASE II

SUMMARY

The Federal Railroad Administration (FRA) sponsored research to examine the performance benefits of four potential modifications to the current methodology used for passenger braking enforcement algorithms (EAs) in Positive Train Control (PTC) applications: Target Approach Management (TAM), specified consist length trains, tuned train types, and adaptive braking.

All four modifications improved braking performance compared to the baseline. PTC braking algorithms are designed so that 99.5 percent of all passenger trains stop before the target, which can impact the efficiency of some consists and vehicles. Improving the performance of the EA without sacrificing safety will allow agencies to operate more efficiently. Table 1 details the overall results.

Table 1. Enhancement Results

	Probability of Stopping Short of the Target	Probability of Stopping Short of the Performance Limit
Baseline	97.90%	21.21%
TAM**	99.99%	0.08%
Specified Consist	99.68%	37.79%
Tuned Trains	99.96%	30.16%
Adaptive (Overall)	99.13%	26.90%

**TAM used a different test matrix.

Additionally, researchers developed a methodology for simulating PTC braking algorithm performance for electric multiple unit (EMU)/diesel multiple unit (DMU) consists. EMU and DMU equipment operate by relaying electronic signals to the brakes and rarely include a brake pipe, which requires changes to the simulation environment to support.

Finally, the project included field testing to demonstrate the modifications to the EA-reflected operational data. Testing was conducted using the baseline, TAM, tuned train type, and specified consist algorithms. Analysis of the test results showed the enhancements could be used to improve the overall EA performance.

BACKGROUND

PTC enforces the operational limits of each train by applying the automatic penalty brake in the event the train is predicted to violate either its movement authority or speed limit. For the PTC system to be effective, the enforcement algorithm must be able to meet the safety objectives of the system without interfering with normal railroad operations.

An industrywide effort with FRA was initiated to improve PTC braking enforcement algorithms. As part of this effort, a methodology was developed to analyze the characteristics of the enforcement algorithm using Monte Carlo simulations validated with field testing.

OBJECTIVES

The primary objective of the project was to identify, develop, simulate, and test methods to improve predictive braking enforcement algorithms for passenger and commuter trains in a PTC system design. Specific objectives included:

1. Modify the Passenger Train Braking Performance Model (PTBPM) so it could model EMU equipment.

2. Perform PTC braking algorithm simulations of the Interoperable Electronic Train Management System (I-ETMS)* and identify potential areas of improvement.
3. Modify the passenger/commuter train enforcement algorithm test application and conduct testing to establish a baseline to which potential improvements could be compared.
4. Use input provided by representatives from intercity passenger and commuter agencies, as well as feedback from the FRA, to develop and implement the highest priority techniques identified in the test application.
5. Support passenger and commuter agencies by providing data and analysis to support their PTC safety analyses.

METHODS

The first task of this project was to modify the simulation environment to support braking algorithm simulations for scenarios involving EMU and DMU equipment. Researchers worked with passenger/commuter railroads to determine the differences between their EMUs and regular passenger locomotives, coaches, and cab cars. Several differences in the control and braking systems were identified. Due to the operational aspects of EMU/DMU equipment, the interface between the EA and the PTC braking algorithm simulation environment required changes. The interface control document (ICD) was updated to include the changes needed. Researchers implemented the changes to the interface in the modeling software so that EMU/DMU could be simulated by PTC braking algorithm software that supported the new interface.

Researchers analyzed the safety and performance of current industry PTC braking algorithms and identified potential areas for improvement. They accomplished this by using the simulation matrix defined in the previous phase of work and reviewing the results of the simulations to determine areas where safety and operational efficiency could be improved. A list of potential improvements was developed, and an industry advisory group (AG) chose the top four highest-priority enhancements to be implemented, namely: TAM, specified consist calculations, tuned train types, and an adaptive algorithm. TAM is currently in use by freight trains, but no analysis using passenger equipment had been completed prior to this project.

Researchers then developed an EA test application with a baseline version of a PTC braking algorithm developed previously. Each enhancement required changes to the baseline algorithm to implement the desired functionality. All enhancements were tested individually using the test application so the relative improvement to the baseline could be analyzed and accurately quantified. Simulations were evaluated on two main metrics related to safety and performance (respectively): the ability to stop at or before the target (probability of overrun), and the ability to stop close to the target (probability of undershoot). The definition of "close" was dependent on speed and may vary for different situations.

Researchers conducted field testing of EA enhancements to verify the improvements shown in the simulation results. Field testing was conducted at the FRA's Transportation Technology Center (TTC) and made use of the facility's Railroad Test Track (RTT). The RTT is a 13.5-mile loop with a variety of grades and curves, making it an appropriate test track for enforcement algorithm testing. The testing was conducted on a portion of this track with a maximum grade of 1.47 percent. The test consist included one GP 40-2 freight locomotive, one F40PH-2 passenger locomotive, and six Amfleet Heritage E-5 railcars.

RESULTS

TAM is a functional concept allowing consists that need to get close to a target to approach at slower speeds without experiencing an unnecessary PTC brake enforcement application. Researchers developed a TAM

* Trademark Wabtec Railway Electronics

process, and during the research project a PTC provider also created its own process and released it. Examining both TAM processes showed that implementing the TAM enhancement would improve performance by allowing consists to get closer to the target location without increasing the probability of overrunning the target. The TAM enhancement improved overall probability of stopping short of the target to at least 99.99 percent.

This study assumes that short trains behave differently than longer trains. A higher ratio of locomotives-to-cars creates less available braking force and has led to an increase in overruns for shorter trains. Modifying the algorithm to calculate a ratio for brake rates based on number of locomotives and cars reduced the overruns – with only a minor impact on operational efficiency. The specified consist length enhancement increased the overall probability of stopping short of the performance limit by 16.58 percent.

The tuned train type enhancement relies on the fact that each passenger and commuter agency may calibrate equipment to meet specific brake rates and operational metrics in their captive fleets. Regression analysis of the data provided by each of four participating agencies was used to calculate brake rates and target offsets. Analysis for the tuned train type enhancement compares only to the baseline results for the four agencies modeled, which had a 98.18 percent overall probability of stopping short of the target and a 23.51 percent probability of stopping short of the performance limit. The overall probability of stopping short of the target increased by 1.78 percent. The tuned train type enhancement increased the overall probability of stopping short of the performance limit by 6.65 percent. When results are broken down by agency, data showed safety improvements for all four case studies. Performance increased in one case study and decreased in the other three case studies.

Using an adaptive algorithm allowed the EA to determine the brake forces more accurately for a specific consist. Brake rates were recorded from prior brake applications and were used to predict the actual brake rate during a PTC braking enforcement. In the analysis for this project, a potential increase in safety was shown. The adaptive braking enhancement increased the overall probability of stopping short of the target by 1.23 percent.

Despite the differences in overall stopping distances, the field test results shared some similarities with the simulation results. Overruns occurred primarily during the lower speed simulations in both the field testing and simulations. Overrun distances during field testing fell within or slightly outside the distribution of stopping locations predicted by the simulation results.

CONCLUSIONS

The primary objective of this project was to identify, develop, simulate, and test methods to improve predictive braking enforcement algorithms for passenger and commuter trains in a PTC system design. Enhancements for TAM, specified consist makeup, and tuned train type were developed, simulated, and field tested.

The last enhancement, adaptive algorithm, was developed and simulated but not field tested due to time limitations. All of the enhancements showed safety improvements compared to the baseline. The TAM enhancement allowed consists to get closer to the target without unwarranted penalty brake enforcements. The specified consist enhancement improved the accuracy of the brake rate calculation, particularly for short trains. The tuned train type enhancement improved the performance of the algorithm by tuning the parameters of the algorithm to the equipment used by each agency. The level of improvement was different for each agency included in the research, based on the level of variation of the equipment used by that agency, but the results did show an overall improvement.

Field testing of the first three enhancements was conducted at TTC, and the results aligned with the simulation outcomes. Most of the overruns in both the field testing and simulations occurred at lower speeds.

A secondary objective was to modify the simulation environment to support simulation of EMU and DMU equipment. A process was developed to support all types of EMU and DMU equipment and the ICD between the simulation environment, and the enforcement algorithm was updated to include the changes needed to allow the necessary data to be sent to the enforcement algorithm. The research team implemented the changes in the modeling software, but simulation of a vendor product could not be completed due to outside constraints. Simulation of braking algorithm performance for EMU and DMU equipment will be completed for each railroad, as needed, outside the scope of this project.

FUTURE ACTION

The methods identified during this project, along with the expansion of the simulation capabilities for passenger and commuter equipment, demonstrate opportunities for continued enhancement of the PTC braking algorithm performance for these train types.

Additionally, before an adaptive algorithm can be implemented, a risk analysis should be performed to fully explore any potential issues. Further evaluation and modeling of the EMU/DMU equipment may provide valuable information for future PTC EA applications.

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KEYWORDS

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