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Positive Train Control (PTC) for railway safety in the United States: Policy developments and critical issues

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ABSTRACT

Nationwide implementation of Positive Train Control (PTC) is underway in the United States. PTC is designed to prevent certain types of train accidents. This paper provides a review of the policy development, operational impact, cost-effectiveness, and critical issues associated with industry-wide PTC implementation. Challenges include interoperability, technological complexity, and limited implementation resources. Emerging critical issues include train operations at restricted speeds, railroad cyber-security risk, broken rail prevention in PTC territories, en route failure of PTC, grade-crossing protection, and opportunities for leveraging PTC-generated big data that require more research from academia, government, and industry.

1. Introduction

Rail transportation plays a vital role in the national economy of the United States. Safety is an obvious priority for rail transportation systems. In the United States, railroad safety has improved through the development and enforcement of safety regulations, along with research and development of advanced technologies over several decades. Although national train accident rates have declined by over 80 percent since 1980 (FRA, 1980, 2015a), accidents still occur annually due to various causes. For example, 25 severe accidents (15 freight accidents and 10 passenger accidents) occurring between 2001 and 2008 were caused by human error (FRA, 2016a).

Train accidents receive substantial media attention and raise the issue of safety and potential solutions, including Positive Train Control (PTC), on the national agenda. Some recent accidents include:

- Amtrak passenger train 501 derailed from a highway overpass near DuPont, Washington, on December 18, 2017, with 3 fatalities and 62 injuries (NTSB, 2018a).
- Amtrak passenger train 89 collided with maintenance-of-way equipment near Chester, Pennsylvania, on April 3, 2016, with 2 fatalities and 39 injuries (NTSB, 2017a).
- Two Union Pacific Railroad freight trains collided near Texarkana, Texas, on September 8, 2015, and led to 2 injuries, release of 4000 gallons of diesel fuel, as well as around $4.66 million damage cost (NTSB, 2017b).

As a safeguard against human error, PTC is expected to prevent train accidents attributable to human error, by slowing or stopping trains automatically. PTC is designed to prevent:

- Train-to-train collisions;
- Derailments caused by excessive speeds;
- Unauthorized incursions into work zones; and
- Movements of trains through misaligned railroad switches.

Complying with the requirements of Subpart I in the Code of Federal Regulations (CFR, 2011), the territory of PTC implementation and operation includes Class I railroads, main lines servicing over 5 million gross tons (MGT) annually and over which toxic- or poisonous-by-inhalation hazardous materials are transported, and main lines involving intercity and commuter passenger trains.

The full implementation of PTC would involve around over 60,000 route miles (AAR, 2017; FRA, 2017b). The large-scale, network-level PTC implementation affects the U.S. rail industry in several aspects, in terms of implementation cost, operational impact, and safety effectiveness (FRA, 2009; Van Dyke and Case, 2010; Peters and Frittelli, 2012; Zhao and Ioannou, 2015: AAR, 2017).

As a federal mandate, PTC technology has been studied in federal regulations and industry reports (RSAC, 1999; FRA, 2009; Van Dyke and Case, 2010; Peters and Frittelli, 2012; GAO, 2015; AAR, 2017). The objective of this paper is to provide readers (especially non-PTC experts) with a full-spectrum introductory view of PTC technology, challenges related to the development and deployment, safety benefits,

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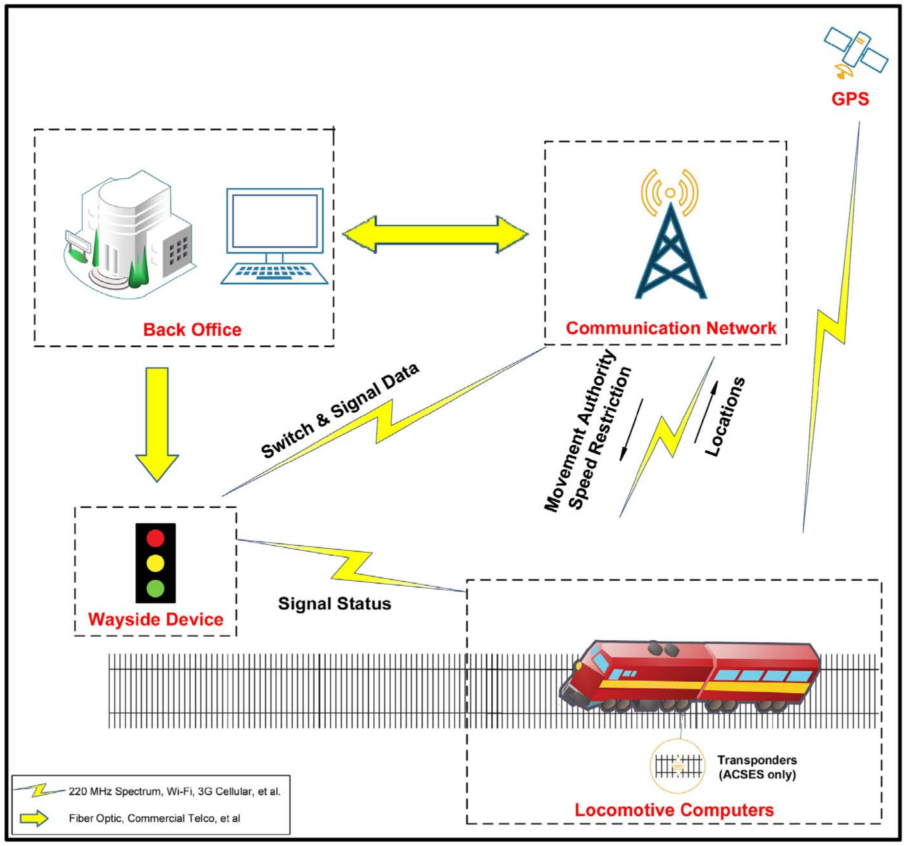

Fig. 1. Schematic illustration of a general PTC system.

and implementation impact and cost. The paper also discusses emerging critical issues in the age of PTC.

2. PTC technology

2.1. The basics of PTC

PTC systems must meet the functionality requirements established by the Rail Safety Improvement Act (RSIA) of 2008 in terms of capability to prevent accidents resulting from the activity or inactivity of train operators. PTC is not a single technology. Instead, it is a suite of performance standards. Railroads are allowed to install different PTC technologies in their respective systems once approved by the Federal Railroad Administration (FRA).

PTC integrates various components (Fig. 1), namely the locomotive computer, wayside device, communication network, and back office (APTA, 2015; AAR, 2017). The locomotive computer is an onboard piece of equipment that accepts speed restriction information and movement authority, so that these data can be compared against the train's location to ensure compliance. The wayside device on the side of the track is capable of monitoring and reporting switch position and signal status to locomotive computers and the back office. The back office is a centralized office for the communication and coordination of train orders, speed restrictions, train information, track authorities, crew sign-in and sign-off, and bulletins, as well as specialized data to and from the wayside and train operational and safety data (GAO, 2015). Three main parts of the back-office system (the back office server (BOS), the geographical information system (GIS), and the dispatch office) interface with other components of the PTC systems. The BOS is a warehouse for various information systems, such as track composition, train consist, and speed limits, to support train operation. Overall, the back office provides the proper speed restriction information and movement authority to the locomotive computer. In the Advanced Civil Speed Enforcement System (ACSES), transponders are used for location tracking, permanent speed restriction (location, speed, and prevailing grade), maximum authorized speed (MAS) restriction, and telling the train when to communication with the Wayside Interface Unit (WIU) at the interlocking ahead. Apart from these components, PTC systems have a communication network capable of transmitting and receiving the data necessary to support an interoperable PTC network. Communications technologies (e.g., 220 MHz radio, Wi-Fi, or cell modems) are commonly used to communicate train locations, speed restrictions, and movements.

Integrated with these components, PTC systems use a combination of communication networks, GPS (or transponders), and fixed wayside signal devices to send and receive data about the location, direction, and speed of trains. Back offices process these data in real time and provide movement authority and speed restriction information to locomotive computers. Then locomotive computers accept the information and compare it against the train's condition to ensure safety compliance. Whenever a train crew fails to properly operate within specified safety parameters, PTC systems automatically apply the brakes and bring the train to a stop.

2.2. History and implementation

Rudimentary elements of PTC have existed since the early 20th century. Regulators and safety advocates have pushed the rail industry to implement PTC systems for decades (FRA, 2016a). In 1990, the National Transportation Safety Board (NTSB) included PTC as one of the most wanted safety technologies in the United States (NTSB, 1991; FRA, 2016a). Railroads subsequently developed and started to deploy train control systems on a small scale. For example, in the 1990s, Amtrak started to deploy the Advanced Civil Speed Enforcement System (ACSES) on its Northeast Corridor, and the Incremental Train Control System (ITCS) on approximately 60 route-miles between Chicago and