COMMAND, CONTROL AND COMMUNICATIONS – AUTOMATIC TRAIN CONTROL SYSTEM

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ABSTRACT: This paper gives an overview of the Automatic Train Control (ATC) system employed to control the Maglev vehicle. The uniqueness of this ATC system is that the train is 'passive', that is its motion is controlled by wayside inverters and not by devices onboard the train. Each train determines its location on the guideway and communicates its location to the wayside office safety server (OSS). The OSS then provides movement authorities to each train. This vital dialog employs the data communication system.

1 INTRODUCTION

The ATC system has three major subsystems: Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS):

ATP: This vital subsystem consists of both wayside and on-board components that ensure safety of train movement on the guideway. These ATP functions include vehicle location, interlocking logic, train door & platform screen door alignment and train speed-distance profile adherence.

ATO: This subsystem provides the automatic control of those functions that occur at speeds below the maximum safe speed determined by the ATP subsystem, to provide smooth and efficient train operation. These ATO functions include programmed station stopping and speed regulation between stations.

ATS: This subsystem collects all pertinent information relative to all the systems and subsystems. ATS provides for system supervision including automatic train routing, schedule keeping and headway control. These combined functions perform train regulation. The ATS subsystem also includes surveillance of each station and inside each vehicle in addition to providing the means of voice communications between passengers and the dispatcher located at central control.

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2 BASIC CONTROL PRINCIPLE

2.1 Virtual Block Vehicle Control

A virtual block system is provided in which a section of guideway is represented by multiple virtual blocks (equivalent to track circuits in a conventional train control system). Each virtual block is held in the memory of the office safety server (OSS) at central control and is geographically the same as the LSM segment fed by an inverter. Communication between wayside and each vehicle is established throughout the transportation system.

The vehicle's carborne equipment determines its position (vehicle-centric) within the transportation system by using DGPS (differential global positioning system) information and Doppler radar data relative to its movement within the transportation system. The actual position within the transportation system is transmitted from each vehicle to the OSS equipment.

The vehicle's onboard ATP equipment also has the same virtual blocks stored in its memory as used by the OSS. This data is used in conjunction with the movement authorities issued by the OSS.

The OSS, knowing the actual position of each vehicle within the transportation system, determines the occupancy status (occupied or unoccupied) of every virtual block within the system.

The CAD system at the office, using this information then generates movement authority limit

(MAL) data which is validated by the OSS and transmitted to each vehicle. Figure 1 illustrates a virtual block control diagram.

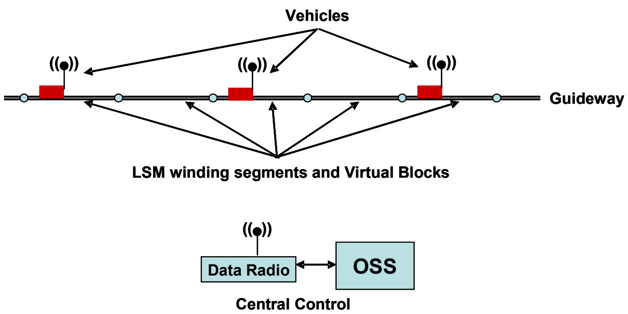

Figure 1. Virtual block vehicle control.

Each vehicle calculates a safety profile to the end of its MAL. If the threshold profile of the MAL is violated by the vehicle, the onboard ATP equipment requests emergency braking of the vehicle and commands the applicable inverter to be shut down. This action ensures the safe stopping of the vehicle.

2.2 Vehicle ATP equipment

Figure 2 below illustrates the vehicle's onboard ATP equipment.

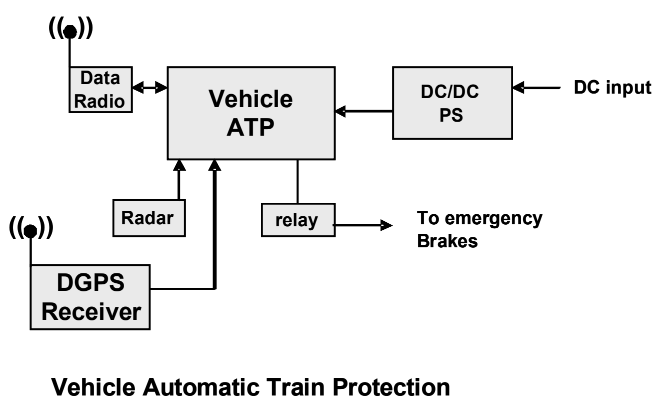

Figure 2. Vehicle ATP equipment

The primary functions of the vehicle's ATP subsystem are to determine its position on the guideway [via DGPS and Doppler radar], transmit its location to central control (OSS), generate a safe speed-distance profile to the end of its MAL, and call for emergency brake application if the profile is violated.

The vehicle's ATP subsystem is interfaced to the vehicle's emergency brakes via relay contacts. Central control can also request a brake application via the OSS/vehicle's data radio system if the dispatcher determines the need to stop all vehicles in a specific area of the guideway.

The ATP transmits the vehicle's location, speed and brake status to central control.

2.3 Inverter ATO functions

The ATO functions of vehicle speed regulation between stations and programmed station stopping are implemented by the General Atomics (GA) control system that regulates all inverters operating in the transportation system. The ATS system interfaces with the inverter control system for scheduling and regulation functions.

2.4 ATS Central Control Office

Figure 3 below shows a simplified block diagram of the central control office.

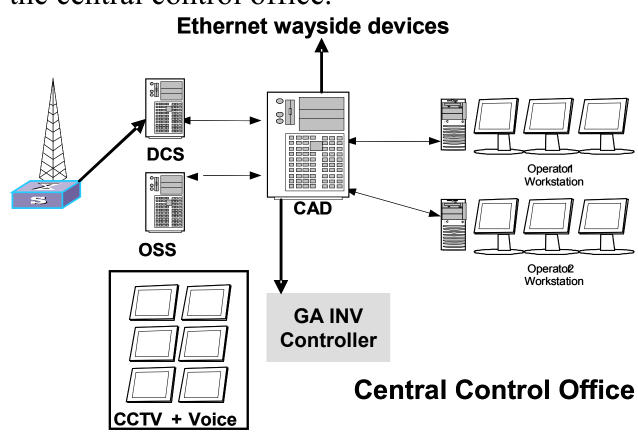

Figure 3. Central Control Office block diagram.

In addition to ensuring safe operation of the system via the OSS, the CAD system will monitor and control all aspects of the transportation system.

The central control functions include Automatic Train Supervision, generation of MALs for all vehicles, control and display of switch positions, vehicle regulation, reports and alarms generation, replay of events, emergency stop requests, CCTV and voice communications, surveillance and interface with the all LSM inverters used for vehicle control and movement.

2.5 Wayside equipment

The major components of the wayside equipment are the Ethernet wired network, remotely controlled cameras and safety processors that monitor and control guideway switches.

Figure 4 illustrates a simplified block diagram of the wayside equipment.

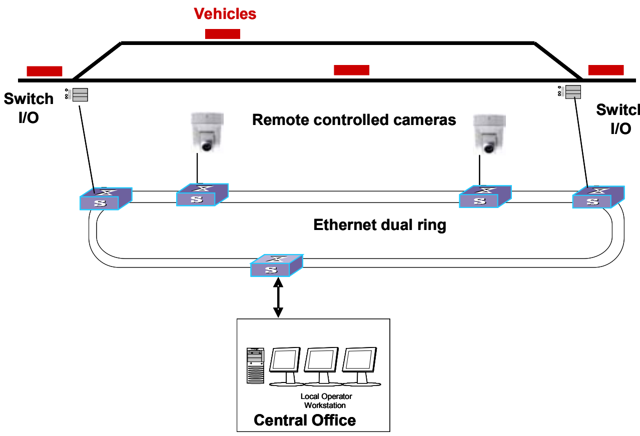

Figure 4. Wayside equipment block diagram.

3 TEST TRACK

Many of the concepts discussed above were demonstrated on the General Atomics' test track. The test track is full-scale, 120 meters in length, with a 50-meter radius curve. The track was completed in November 2004. Figure 5 shows a picture of the test track.

The test track is currently being extended in length. When extended, the maximum test track speed for a vehicle will approaches 20 m/s.

Figure 5. Test track.

3.1 *Test track control room equipment*

Figure 6 illustrates a block diagram for the test track control room equipment used in train control. A safety processor, implemented with Union Switch & Signal's (US&S) Microlok II vital programmable controller, is in constant communication with the vehicle's ATP onboard unit. If for some reason the vehicle violates its speed-distance threshold profile, the ATP sends a message to the inverter (via Microlok II) to be shut down.

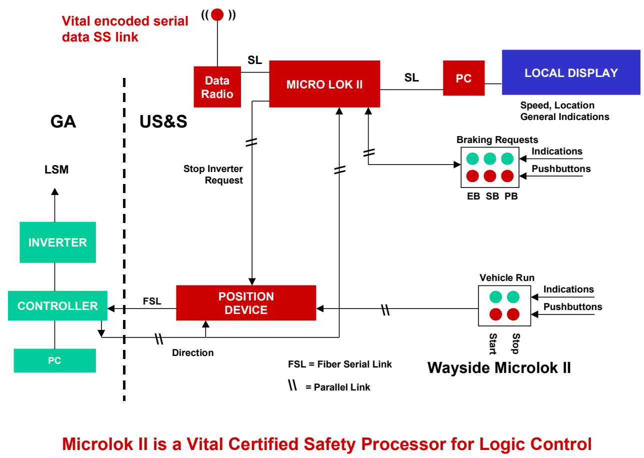

Figure 6. Test track control room block diagram for train control.

Figure 7 is a picture of the test track control room equipment. All the equipment is located in one 19" open rack.

Figure 7: Control room equipment rack

The Microlok II unit is located at the bottom of the rack. The spread spectrum 900 MHz communication data radio is located at the top of the rack. This data radio channel supplies the continuous communications between the vehicle and Microlok.

Also at the top of the rack is a 450 MHz RF data radio modem that receives position information from the optical sensors located on the vehicle. This position device conveys precise location of the vehicle in each LSM winding. This data is used by the inverter for motion control of the vehicle.

Located near the top of the rack are push-buttons (controls) and lamps (indications) that can be used to stop the vehicle. A request to stop the vehicle is initiated by an input to Microlok II and transmitted to the vehicle's ATP via the SS 900 MHz data channel.

3.2 Test track vehicle equipment

Figure 8 shows the onboard ATP equipment rack. This unit was configured using a typical US&S cab signaling ATP unit. The ATP unit determines its location on the guideway using DGPS and Doppler radar. The unit also has a guideway map (virtual blocks) embedded into it for use in the determination of speed-distance profile for the vehicle.

If the threshold of this embedded profile is violated, see figure 9, a request for emergency braking is issued along with a message to Microlok II (via data radio) to shut down the inverter.

Figure 8.Vehicle onboard ATP rack.

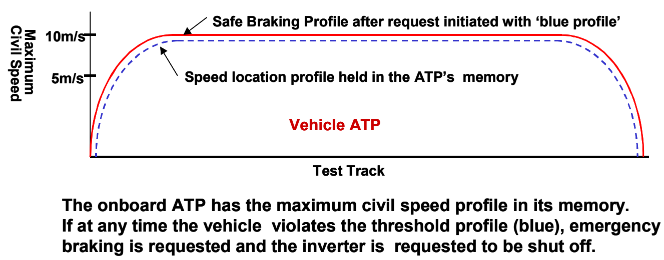

Figure 9: Embedded speed profile

3.3 Test track optical position equipment

Figure 10 shows the optical position device. The optical sensor is mounted on the body of the vehicle. This sensor 'reads' the black/white bar code located along the guideway structure. The pulses generated by the sensor are transmitted back to central control via BFSK modulation of the 450 MHz data radio. This data is decoded in real time to locate the vehicle within the wavelength of one of the LSM coils.

The leading and falling edges of the black bars represent 15 degrees (18 mm) of the 360 degree wavelength (432 mm) for one of the three LSM coils. The beginning of each wavelength is represented by double black (black-white-black) bar which has the width of a normal 15 degree black bar.

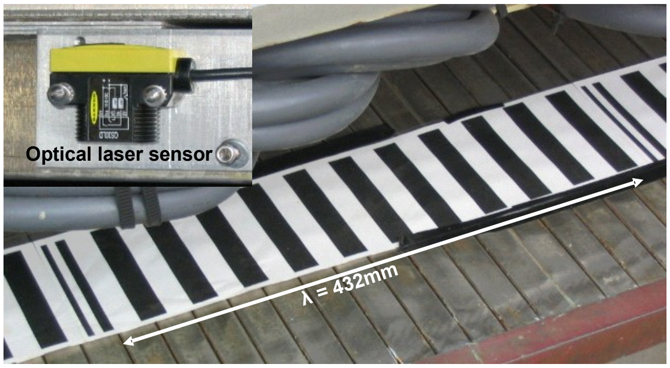

Figure 10: Optical position device

4 CUP DEMONSTRATION SYSTEM

A demonstration system is planned to be constructed at California University of Pennsylvania (CUP) in California, Pennsylvania, located about 60 miles southwest of Pittsburgh. When completed, this system will be 7.4 km in length with four stations, and 3 vehicles, connecting the upper and lower campus. The system will serve the main campus, the city, and student housing/sports facilities on the upper campus. Initially, it will be used to demonstrate the all weather, grade climbing, ride quality capabilities and automatic train control of a maglev system.