

TITLE OF THE INVENTION

TRAIN CONTROL SYSTEM, ON-VEHICLE DEVICE, AND WAYSIDE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a train control system, an on-vehicle device, and a wayside device.

2. Description of the Related Art

In a railway system, train control is executed by a signalling system such that collision of a train does not happen. In the related art, a train position is grasped using a track circuit. However, recently, instead of the track circuit, a wireless train control system to perform wireless communication between the train and the ground is introduced for introduction and maintenance expense reduction of facilities.

In the wireless train control system, an on-vehicle device mounted on the train continuously calculates position information of the train and grasps a train position. However, for example, when the train finishes a one-day operation and stops until a next operation starts, a power supply of the on-vehicle device is generally turned off. For this reason, when the power supply of the on-vehicle device is turned on to start the next operation, it is difficult to grasp the train position because the

position information of the train is reset when the power supply of the on-vehicle device is turned off.

Technology for grasping the train position before and after the power supply of the on-vehicle device is turned on/off is disclosed in JP-2007-015517-A. In JP-2007-015517-A, "an position management device transmits position information obtained from a wayside control device immediately before a power supply of the wayside control device is turned off to the wayside control device, when the power supply of the wayside control device is restored from an OFF state" is described.

SUMMARY OF THE INVENTION

In JP-2007-015517-A, because the position of the train is grasped after the power supply of the on-vehicle device is restored, the wayside device cannot grasp the position of the train, until the power supply of the on-vehicle device is restored after the power supply is turned off. If the train moves due to unintended slippage in a state in which the power supply of the on-vehicle device is turned off, the train may collide with other train. For this reason, the above technology is not preferable from the viewpoint of train safety.

Meanwhile, to start the power supply of the on-vehicle device at all times to grasp the train position is not preferable from the viewpoint of energy saving.

An aspect of the present invention provides a train control system including: an on-vehicle device mounted on a vehicle traveling on a track, the on-vehicle device including a sensor to detect a movement of the vehicle, an on-vehicle control unit to calculate position information of the vehicle, and an on-vehicle wireless device to output a signal of the sensor or the on-vehicle control unit to the outside; and a wayside device that performs wireless communication with the on-vehicle wireless device and controls the vehicle, wherein the train control system includes a first mode in which the on-vehicle control unit calculates the position information based on a detection result from the sensor and the on-vehicle wireless device transmits the position information to the wayside device and a second mode in which feeding to the on-vehicle control unit is interrupted and the wayside device calculates the position information based on the detection result from the sensor acquired via the on-vehicle wireless device.

The present invention can detect a train position of a vehicle at a stop with small consumption power.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent from the following description of embodiments with reference to the accompanying drawings in which:

Fig. 1 is a diagram illustrating an example of a configuration of a wireless train control system according to a first embodiment;

Fig. 2 is a diagram illustrating an example of a configuration of on-vehicle device for train protection according to the first embodiment.

Fig. 3 is a diagram illustrating an example of a process flow of wayside device for train protection according to the first embodiment;

Fig. 4 is a diagram illustrating an example of a configuration of an on-vehicle device according to a second embodiment;

Fig. 5 is a diagram illustrating an example of a process flow of wayside device for train protection according to the second embodiment;

Fig. 6 is a diagram illustrating an example of a configuration of an on-vehicle device according to a third embodiment;

Fig. 7 is a diagram illustrating an example of a process flow of the on-vehicle device for train protection according to the third embodiment; and

Fig. 8 is a diagram illustrating an example of an outline of a wireless train control system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings, wherein like reference numerals refer to like parts throughout.

First embodiment

An outline of a wireless train control system will be described using Fig. 8. Vehicles 801 and 802 are vehicles that travel along a track. The vehicle 801 calculates an own vehicle position 806 from position information obtained when the vehicle 801 passes through a ground unit 803 and a movement distance 805 obtained from a sensor such as a tacho-generator mounted on an axle of the vehicle 801 and transmits the own vehicle position 806 to a wayside control device 804 by wireless communication. The wayside control device 804 calculates a limited moving authority 807 to be a limit spot where the vehicle 801 can travel safely, based on position information of other

vehicle such as a vehicle 802, and sends the limited moving authority 807 back to the vehicle 801. The vehicle 801 creates a brake pattern 808, based on the own vehicle position information 806, deceleration (brake) performance of the own vehicle, and the received limited moving authority 807. The travel is controlled not to surpass a speed of the brake pattern 808, so that the vehicle can be prevented from moving beyond the limited moving authority 807, and the vehicle 801 does not collide with the traveling vehicle 802. If the vehicle 802 moves forward, the limited moving authority 807 is also updated with a forward place of the vehicle 802. Therefore, the vehicle 801 can travel continuously.

A gist of the present invention is to execute a process capable of being calculated at the ground side to minimize consumption power and an calculation cost of an on-vehicle device, in consideration of the fact that there is no safety problem even though responsiveness of position detection of the vehicle is lower than responsiveness in a normal operation, when the vehicle stops for a predetermined time, for example, when the vehicle stops until a next commercial operation starts from an end of a commercial operation.

Fig. 1 illustrates an example of a configuration of a wireless train control system according to a first

embodiment of the present invention. The wireless train control system according to this embodiment includes a wireless device A 100 disposed on a train, on-vehicle device for train protection 101, a sensor A 102, a sensor B 103, a feeding control unit 106, an auxiliary power supply (APS) 107, a battery 108, a converter 109, a transformer 110, a pantograph 111, an overhead line 112, and a wireless device B 104 and wayside device for train protection 105 disposed on a ground. The on-vehicle device for train protection 101 may be called an on-vehicle control unit.

The overhead line 112 supplies power to the train and a third rail may be used at the time of being applied to a monorail. The pantograph 111 is a charging mechanism that receives the power from the overhead line 112. The transformer 110 transforms the power received from the pantograph. The converter 109 converts the power transformed by the transformer 110 into direct-current power. The APS 107 is a power conversion mechanism and supplies the power to a lighting fixture in the train. The battery 108 is a storage mechanism to store the power from the converter 109 and is an uninterruptible power supply (UPS), for example. The feeding control unit 106 is a mechanism to control supplying of power (ON/OFF) to the on-vehicle device for train protection 101, each sensor, and the wireless device A to be devices surrounded by a dotted

line. In a method of controlling feeding, a breaker may be provided on each device or a power line to perform feeding to each device and the breaker may be controlled. The on-vehicle device for train protection 101 calculates a train position based on information measured by the sensor A 102 and the sensor B 103 and transmits the calculated train position to a wayside device by wireless communication. Thereby, the on-vehicle device is configured.

The wayside device for train protection 105 calculates the limited moving authority of each train where each train can travel safely, based on the transmitted train position of each train, and transmits the limited moving authority to the on-vehicle device for train protection 101 of each train by the wireless communication.

Each of the on-vehicle device for train protection 101 and the wayside device for train protection 105 is a device that includes two CPUs (CPU-A 200 and CPU-B 201) and a comparator 202 and can compare outputs of the two CPUs. The outputs of the individual CPUs are compared by the comparator. When the outputs are mismatched with each other, safety is secured by controlling the device for train protection to the safety side and stopping the device for train protection, in consideration of the possibility of failure of the CPU, regardless of output content. When the outputs of the CPUs are matched with each other, the

matched outputs are transmitted to the outside. The number of CPUs may be three or more. In this case, when the outputs of CPUs equal to or more than the majority of CPUs are matched with each other, the outputs thereof are transmitted to the outside.

The converter 109 may not be provided in the case of a direct-current overhead line and the battery 108 may be a storage mechanism that is not connected to the converter 109 and is previously charged.

Fig. 2 illustrates an example of a portion relating to the on-vehicle device for train protection of the on-vehicle device. If the on-vehicle device for train protection 101, the sensor A 102, and the sensor B 103 have a configuration illustrated by (1) of Fig. 2, each CPU acquires information of both the sensor A 102 and the sensor B 103 and compares the information of the sensor A 102 and the sensor B 103 or position information calculated from the sensor A 102 and position information calculated from the sensor B 103. If a difference thereof is large, it is determined that the sensor fails and an abnormality process is executed and if the difference is within an error range, a process to determine position information used for control based on the information of both sides is executed. After the process is executed, the outputs of the individual CPUs of these processes are compared by the

comparator 202. If the outputs are matched with each other, the outputs are transmitted to the outside and if the outputs are mismatched with each other, the abnormality process to control the on-vehicle device for train protection 101 to the safety side and stop the on-vehicle device for train protection 101 is executed. Each CPU acquires absolute position information (not illustrated in the drawings) acquired when the vehicle passes through the ground unit and information from each sensor and calculates more accurate position information of the vehicle.

The information compared between the CPUs may be the information of the plurality of sensors or an calculation result such as position information operated based on the information of the plurality of sensors, as in the case of (1) of Fig. 2. When the two tacho-generators are attached to the same axle and the same data can be acquired from the plurality of same sensors, the information compared between the CPUs may be the information of the sensor acquired by each CPU or an calculation result such as position information calculated based on information of one sensor, as in the case of (2) of Fig. 2.

The sensor A 102 and the sensor B 103 are sensors that can use the information of the sensor as the position information. The sensor A 102 and the sensor B 103 may be high-precision sensors rarely affected by shaking of the

train and an external environment, in consideration of a use for train control. For example, in the related art, a tacho-generator and a pulse generator (PG) are used as the sensors and position information is generated using a cumulative movement distance calculated based on the information of the sensors. In addition, the sensor A 102 and the sensor B 103 can be configured differently by forming the sensor A 102 using the tacho-generator and the sensor B 103 using the pulse generator and redundancy is realized for sensing abnormality peculiar to the sensors. In addition, the redundancy can be realized using three or more sensors.

Next, detection modes of the train to be a gist of the present invention will be described. For example, because it is required to immediately execute the abnormality process on the moving train at the time of the abnormality such as the failure of the sensor and the failure of the CPU during the commercial operation, responsiveness when a comparison result is mismatching becomes important. For this reason, during the commercial operation, in a first mode, the position information calculated based on the information of the sensor A 102 and the sensor B 103 is compared by the on-vehicle device for train protection 101. At this time, the feeding control unit 106 feeds power to the on-vehicle device for train

protection 101, the sensor A 102, the sensor B 103, and the wireless device A. During the commercial operation, because the power is received from the overhead line 112, power from the APS 107 may be supplied. When a comparison result is matching, information thereof is transmitted to the wayside device for train protection 105 via the wireless device A 100 and the wireless device B 104 and is used as the position information of each train for control. Because the train position can be calculated without performing communication with the wayside device, a train position can be grasped early by system.

Meanwhile, for example, when the train stops for a long time after the commercial operation ends, the speed of the train is low even though the train is moved by a wind or the like. For this reason, high responsiveness is not acquired. Therefore, during the stop, in a second mode, instead of calculating/comparing the position information by the on-vehicle device for train protection 101, the information acquired from the sensor A 102 and the sensor B 103 is transmitted to the wayside device for train protection 105 via the wireless device A 100 and the wireless device B 104 and the position information calculated by the each CPU based on the received information of the sensor A 102 and the sensor B 103 is compared by the wayside device for train protection 105.

At this time, the feeding control unit 106 interrupts feeding to the on-vehicle device for train protection 101 and feeds power to the sensor A 102, the sensor B 103, and the wireless device A 100. During the stop, when the pantograph 111 falls down and cannot receive power from the overhead line 112, power of the battery 108 may be supplied. When the power can be received from the overhead line 112 even though the train stops for a long time, the power of the APS 107 may be supplied. If the train which needs to stop moves for a long time even though the train moves slowly, the train moves by a distance of some degree. For this reason, movement detection of the train becomes important during the stop.

Fig. 3 illustrates an example of a control flow of the wayside device for train protection 105. The information is received from the on-vehicle device (300) and the position information of the train is calculated by each CPU based on the information of the sensor A 102 and the sensor B 103 received from the on-vehicle device (301). The position information calculated from the sensor A 102 and the position information calculated from the sensor B 103 are compared and it is confirmed whether a difference is in an error range (302). If the difference is not in the error range, an abnormality process A in which it is assumed that the sensor fails is executed (303). If the

difference is in the error range, the position information used for the control is determined based on the two position information (304) and it is confirmed whether the train stops (305). When it is determined that the train moves, an abnormality process B in which other train is prevented from entering a section where the train may exist or movement of the train is transmitted to a operator is executed (306). When it is determined that the train does not move, a normal process such as update of the position information and transmission of the limited moving authority updated based on the position information is executed (307). The outputs of the individual CPUs of the processes 303, 306, and 307 are compared by the comparator 202 (308). When a comparison result is mismatching, an abnormality process C in which the on-vehicle device for train protection 101 is controlled to the safety side and is stopped is executed (309) and when the comparison result is matching, the outputs thereof are transmitted to the outside (310).

In this way, the power supply of the on-vehicle device for train protection 101 in which the power consumption of the on-vehicle device is large can be turned off with respect to an application in which the power supply of the on-vehicle device is not turned off even

after the commercial operation ends and the train detection can be performed while the consumption power is decreased.

With respect to the information transmitted from the wayside device to the on-vehicle device in the second mode, the information acquired from the sensor may be transmitted. If unnecessary data is omitted by a controller of the wireless device and data is processed, the communication time/consumption power can be reduced.

With respect to a communication interval of the on-vehicle device and the wayside device in the second mode, different from the commercial operation, the information acquired from the sensor does not need to be transmitted from the on-vehicle device to the wayside device frequently and a power consumption amount of the wireless device can be decreased by storing the data in a buffer and increasing the communication interval. In addition, the communication interval may be determined according to train position of the train at the stop on the line. When other train does not exist near the train at the stop, the communication frequency can be further decreased. In addition, weather data such as the strength of the wind and the rain may further be acquired and the safety may be increased by increasing the communication frequency in the case of climatic conditions in which train is easy to move unintentionally.

With respect to switching timing of the mode, the mode may be switched manually and may be switched automatically when the pantograph 111 falls down or when the power supply of the on-vehicle device for train protection 101 is turned off. The present invention is not limited to "stop" until the commercial operation restarts from the end of the commercial operation and can be used when high responsiveness is not required in the position detection of the train. For example, when the failure of the on-vehicle device for train protection is detected during the commercial operation, at least the position information of the train is transmitted to the wayside device without using the on-vehicle device for train protection, so that the detection of train position at the time of the restoration can be rapidly performed. In addition, when a train schedule is disrupted and the train stops for a long time or moves slowly, the mode may be switched into the second mode to decrease an operation cost in the on-vehicle device.

Second embodiment

Fig. 4 illustrates an example of a configuration of an on-vehicle device according to a second embodiment of the present invention. This embodiment is the same as the first embodiment in a wayside device and a feeding control

unit of the on-vehicle device. However, this embodiment is different from the first embodiment in that a different sensor is used in each of first and second modes. That is, in the second mode, a cheap sensor with low precision can be used as compared with the first mode, as long as it is known that a train moves due to some abnormality. In the case of the first mode, a feeding control unit 106 feeds power to an on-vehicle device for train protection 101, a sensor A 102, a sensor B 103, and a wireless device A 100 and in the case of the second mode, the feeding control unit 106 feeds power to an acceleration sensor C 400 and an acceleration sensor D 401 in addition to the sensor A 102, the sensor B 103, and the wireless device A 100 and interrupts feeding to the on-vehicle device for train protection 101. The power may be fed to a vibration source to be described below, at least when failure is diagnosed.

During a stop, information when the sensor fails and an output becomes 0 and information when the train stops and an output becomes 0 are not distinguished from each other and the failure of the sensor cannot be detected only by acquiring both information of the failed sensor and a normal sensor and comparing the information by a wayside device for train protection 105. In this state, if the other sensor fails, the failure of the sensor exists latently and detection cannot be performed by the wayside

device for train protection 105 even though the train moves. For this reason, when sensors with low reliability in which the probability of both the sensors fail during the stop cannot be ignored are used, it is more preferable to diagnose the failure of the sensor during the stop.

Therefore, in Fig. 4, an acceleration sensor that has a low cost and small consumption power and can calculate a cumulative movement distance and use the cumulative movement distance as position information is used as the sensor in the second mode. Because the acceleration sensor can diagnose the failure by applying a vibration intentionally, the failure diagnose is enabled even when the train stops. For this reason, if the acceleration sensor is used in the second mode, safety can be secured even though the sensor with the low reliability and cost is used.

In a control flow of the wayside device for train protection 105 in this case, a failure diagnosis process (500) to confirm whether a vibration result is included in information of the sensor is added as illustrated in Fig. 5.

Timing when the vibration is applied and the failure diagnose according to whether the vibration is detected is performed may be any timing. If it is previously known that the mode changes to the second mode, the failure diagnose can be executed without applying the vibration by

executing the failure diagnose in the middle of the first mode. In addition, if both the acceleration sensors are disposed to be adjacent to each other and a vibration source to apply the vibration is disposed near both the sensors, failures of the plurality of acceleration sensors can be diagnosed by one vibration source.

In this embodiment, because the cheap acceleration sensors may be attached newly to the existing on-vehicle device, mounting become easy. In addition, different wireless devices may be used in the first and second modes.

Third embodiment

Fig. 6 illustrates an example of a configuration of an on-vehicle device according to a third embodiment. A storage medium 600 and a controller 601 are added, a power supply of on-vehicle device for train protection 101 is turned off after a commercial operation ends, and the controller 601 stores information of a sensor while the power supply is turned off in the storage medium 600. Then, when the commercial operation starts, the on-vehicle device for train protection 101 starts up and the on-vehicle device for train protection 101 acquires the information of the sensor while the power supply is turned off from the storage medium 600 by each CPU and compares position information calculated based on the information. The

controller may have only a function of storing the information of the sensor in the storage medium and may use the sensor with low cost and low power consumption. In this way, the consumption power can be reduced by turning off the power supply of the on-vehicle device for train protection 101 with large consumption power.

Fig. 7 illustrates an example of a control flow of the on-vehicle device for train protection 101 in the above case. In a state in which the power supply is turned off (700), the on-vehicle device for train protection 101 starts up (701) and information of a sensor A 102 and a sensor B 103 while the power supply is turned off is acquired from the storage medium 600 (702). The position information is calculated from the acquired information of the sensor A 102 and the sensor B 103 (703) and it is confirmed whether a difference of the position information is in an error range (704). If the difference is not in the error range, an abnormality process A in which it is assumed that the sensor fails is executed (705). If the difference is in the error range, the position information used for the control is determined based on the two position information (706) and it is confirmed whether the train does not move (707). When it is determined that the train moves, an abnormality process B in which the position of the train being unsettled is transmitted to a wayside

device for train protection is executed (708). When it is determined that the train does not move, a normal process in which the position information is transmitted to the wayside device for train protection is executed (709). The outputs of the individual CPUs of the processes 705, 708, and 709 are compared by a comparator 202 (710). When a comparison result is mismatching, an abnormality process C in which the on-vehicle device for train protection 101 is controlled to the safety side and is stopped is executed (711) and when the comparison result is matching, the outputs thereof are transmitted to the outside (712).

As such, the mode is switched, so that the power supply of the on-vehicle device for train protection 101 can be turned off while a train stops after a commercial operation ends. Therefore, consumption power can be reduced.

The present invention is not limited to the embodiments described above and various modifications are included. For example, the embodiments are described in detail to facilitate the description of the present invention and are not limited to embodiments in which all of the described configurations are included. In addition, a part of a configuration of a certain embodiment can be replaced by a configuration of another embodiment and the configuration of another embodiment can be added to the

configuration of the certain embodiment. For a part of a configuration of each embodiment, addition, deletion, and replacement of the configuration of another embodiment are enabled. For example, the present invention can be applied to any train including one vehicle or a plurality of vehicles. In addition, even when the present invention is applied to a moving object system that travels on a track such as a monorail and executes control by wireless communication, an effect of the present invention is obtained. In addition, the present invention can be carried out by appropriately selecting an APS 107 and a battery 108 in a battery electric train travelling on a non-overhead line section or a train loaded with an engine. In addition, information such as a program, a table, and a file for realizing each configuration may be stored in a recording device such as a memory, a hard disk, and a solid state drive (SSD) and may be stored in a recording medium such as an IC card, an SD card, and a DVD.

What is claimed is:

1. A train control system comprising:

an on-vehicle device mounted on a vehicle traveling on a track, the on-vehicle device including a sensor(102,103,400,401) to detect a movement of the vehicle, an on-vehicle control unit(101) to calculate position information of the vehicle, and an on-vehicle wireless device(100) to output a signal of the sensor(102,103,400,401) or the on-vehicle control unit(101) to the outside; and

a wayside device(105) that performs wireless communication with the on-vehicle wireless device(100) and controls the vehicle, wherein

the train control system includes a first mode in which the on-vehicle control unit(101) calculates the position information based on a detection result from the sensor(102,103,400,401) and the on-vehicle wireless device(100) transmits the position information to the wayside device(105) and a second mode in which feeding to the on-vehicle control unit(101) is interrupted and the wayside device(105) calculates the position information based on the detection result from the sensor(102,103,400,401) acquired via the on-vehicle wireless(100) device.

2. The train control system according to claim 1, wherein

when the vehicle travels, the position information is calculated by the first mode and when the vehicle stops for a predetermined time, the position information is calculated by the second mode.

3. The train control system according to claim 1, wherein

the on-vehicle device further includes a feeding control unit(106) that feeds power to the sensor(102,103,400,401), the on-vehicle control unit(101), and the on-vehicle wireless device(100) in the first mode and interrupts feeding to the on-vehicle control unit(101) and feeds power to the sensor(102,103,400,401) and the on-vehicle wireless device(100) in the second mode.

4. The train control system according to claim 1, wherein

the sensor(102,103,400,401) includes a first sensor(102,103) and a second sensor(400,401) and the on-vehicle device further includes a feeding control unit(106) that feeds power to the first sensor(102,103), the on-vehicle control unit(101), and the on-vehicle wireless device(100) in the first mode and interrupts feeding to the first sensor(102,103) and the on-vehicle control unit(101)

and feeds power to the second sensor(400,401) and the on-vehicle wireless device(100) in the second mode.

5. The train control system according to claim 4, wherein

the second sensor(400,401) is an acceleration sensor, the on-vehicle device includes a vibration source that applies a vibration to the acceleration sensor(400,401), and the acceleration sensor(400,401) detects a failure of the acceleration sensor(400,401) based on whether the vibration is detected, in the second mode.

6. The train control system according to claim 3, wherein

the feeding control unit(106) feeds power obtained from an overhead line(112) or a third rail to the sensor(102,103,400,401) and the on-vehicle control unit(101) in the first mode and feeds power of a battery(108) of the vehicle to the sensor(102,103,400,401) in the second mode.

7. The train control system according to claim 1, wherein

in the on-vehicle wireless device(100), a communication interval in the second mode is longer than a communication interval in the first mode.

8. An on-vehicle device mounted on a vehicle traveling on a track and performs wireless communication

with a wayside device(105) to control the vehicle based on position information of the vehicle, comprising:

- a sensor(102,103,400,401) that detects a movement of the vehicle;

- an on-vehicle control unit(101) that calculates position information of the vehicle; and

- an on-vehicle wireless device(100) that outputs a signal of the sensor(102,103,400,401) or the on-vehicle control unit(101) to the outside, wherein

- the on-vehicle device includes a first mode in which the on-vehicle control unit(101) calculates the position information based on a detection result from the sensor(102,103,400,401) and the on-vehicle wireless device(100) transmits the position information to the wayside device(105) and a second mode in which feeding to the on-vehicle control unit(101) is interrupted and the on-vehicle wireless device(100) outputs the detection result from the sensor(102,103,400,401) to the wayside device(105) to calculate the position information.

9. A wayside device(105) that performs wireless communication with an on-vehicle device including a sensor(102,103,400,401) to detect a movement of a vehicle traveling on a track and an on-vehicle control unit(101) to output position information of the vehicle to the outside via an on-vehicle wireless device(100) and controls the

vehicle based on the position information of the vehicle,
the wayside device(105) comprising:

a first mode in which the on-vehicle control
unit(101) receives the position information calculated
based on a detection result from the
sensor(102,103,400,401); and

a second mode in which the on-vehicle device
interrupts feeding to the on-vehicle control unit(101) and
the wayside device(105) receives the detection result from
the sensor(102,103,400,401) and calculates the position
information.