

Description

Operation of a rail vehicle

The invention relates to a method for operating a rail vehicle, to a corresponding rail vehicle and to a corresponding station monitoring system.

Track sections of metropolitan light railway networks or urban rail transit systems (such as urban/suburban commuter railway systems or subways, for example) are often arranged underground in tunnels in urban areas. In the event of a breakdown of a rail vehicle (also referred to as a train) carrying railway customers or passengers, it is preferable to avoid evacuating passengers in the tunnels, which typically are constructed to very narrow geometries. Thus, in the event of incidents occurring it is attempted for operational and safety-related reasons to pilot the rail vehicle to the nearest station (e.g. train station or stop) ("safe-haven principle").

If the urban transit system is being operated in an unattended or driverless mode (also referred to as "GoA4 operation"), a rail vehicle may enter the station only if its entry has been authorized by the station and if information representing the authorization has been successfully transmitted to the arriving rail vehicle via a communication link. A station can change its state or status under the control of safety equipment, for example if open platform screen doors are identified along with the consequent exposure to danger of persons that may be present in the track area.

If there is a failure of the communication link between a trackside track monitoring system and an onboard train control device in the rail vehicle (i.e. for example between the track monitoring system and the rail vehicle), the rail vehicle can no longer be informed about potential hazard situations. For this reason, in the event of a failure of the communication link, it is possible for the rail vehicle to continue in motion only as far as an end to a currently valid track warrant ("movement authority" (MA)), i.e. up to the end of a section for which the status cannot change due to another event. For example, the rail vehicle is controlled in such a way that it is stopped immediately before entering the station. It is then not possible for the rail vehicle to enter the station (even if no hazard situation exists) until either the communication link is restored or personnel arrive at the rail vehicle and manually drive the rail vehicle on sight into the station. Both events can last a considerable length of time.

Since it is possible in certain circumstances for the passengers to disembark from the rail vehicle independently after it has come to a halt, the probability that the passengers will want to leave the rail vehicle increases, particularly if the rail vehicle remains stationary for a relatively long time. However, having passengers wandering about in the track area is undesirable, in particular because it is then no longer possible to assure safe operation of rail vehicles on the affected section of track. Rather, train operation in the vicinity of the stopped rail vehicle must then be suspended at least temporarily in order to avoid putting the passengers at risk. Thus, a technical failure of the communication link between the rail vehicle and the track monitoring system may result in a safety-critical situation

both for the passengers and for the ongoing train operation, leading to a considerable delay in the running of train operation.

The object of the invention consists in avoiding the disadvantages cited in the foregoing and ensuring efficient train operation in particular in the event of failure of the communication link between rail vehicle and track monitoring system.

This object is achieved according to the features of the independent claims. Preferred embodiment variants may be derived in particular from the dependent claims.

In order to achieve the object, a method for operating a rail vehicle is proposed

- in which a failure of a communication link between a track monitoring system and the rail vehicle is detected by the track monitoring system and by the rail vehicle,
- in which the rail vehicle continues in motion even in the event of a failed communication link as long as no hazard state is identified by the track monitoring system and by the rail vehicle.

The hazard state is in particular an (operating) state of the section of track or of the rail vehicle that is recognized or predefined as unfavorable, endangering safety or inadmissible. The hazard state can be determined for example by means of sensors on the section of track or on the rail vehicle. It is also possible that the hazard state can be inferred from information or data supplied by sensors.

The rail vehicle can continue in motion as long as no hazard state is identified both by the track monitoring system and by the rail vehicle.

A development is that the rail vehicle is braked, in particular brought to a halt, if a hazard state is identified.

Another development is that a power supply to the rail vehicle is interrupted by the track monitoring system if the hazard state is determined by the track monitoring system.

In particular it is a development that the rail vehicle is braked, in particular brought to a halt, if an interruption to the power supply is detected by the rail vehicle.

It is also a development that the rail vehicle is braked, and in particular brought to a halt, if the hazard state is determined by the rail vehicle.

It is furthermore a development that the hazard state is identified by the track monitoring system by means of at least one track sensor and/or by means of at least one station monitoring system.

A next development consists in the hazard state being identified by the rail vehicle by means of sensors and/or information available in the rail vehicle.

An embodiment is that the hazard state includes at least one of the following events:

- a malfunction of the rail vehicle,
- a malfunction or an obstruction on the section of track to be traveled on,

- a malfunction of the station being approached,
- a hazard situation in the station being approached.

An alternative embodiment variant consists in the rail vehicle continuing in motion even in the event of a failed communication link at least partially at reduced speed as long as no hazard state is identified by the track monitoring system and by the rail vehicle.

A next embodiment is that the communication link is a wireless communication link.

The communication link can be in particular an arbitrary radio link between the rail vehicle and the track monitoring system.

In order to achieve the object specified hereinabove, a rail vehicle is also proposed having a processing unit and having a communication unit, wherein the processing unit is configured

- to detect a failure of a communication link between a track monitoring system and the rail vehicle,
- to allow the continued movement of the rail vehicle even in the event of a failed communication link as long as no hazard state can be identified and as long as no interruption to a power supply to the rail vehicle can be detected.

A development consists in the processing unit being configured to initiate a braking action on the part of the rail vehicle if a hazard state can be identified or if the interruption of the power supply to the rail vehicle can be detected.

An additional embodiment is that the processing unit is configured to allow the continued movement of the rail vehicle

even in the event of a failed communication link at least partially at reduced speed as long as no hazard state can be identified and as long as no interruption of the power supply to the rail vehicle can be detected.

The object cited in the foregoing is also achieved by means of a track monitoring system having a processing unit and having a communication unit, wherein the processing unit is configured

- to detect a failure of a communication link between the track monitoring system and a rail vehicle,
- to supply power to the rail vehicle even in the event of a failed communication link as long as no hazard state can be identified.

In particular, the processing unit of the track monitoring system can be configured to detect a malfunction in the station.

A development is that the processing unit is configured to interrupt the power supply to the rail vehicle if a hazard state can be identified.

The remarks made in relation to the method are applicable analogously to the devices, i.e. the rail vehicle and the track monitoring system.

The processing unit cited herein can be embodied in particular as a processor unit and/or an at least partially hardwired or logic circuit arrangement which is configured for example in such a way that the method as described herein can be performed. Said processing unit can be or comprise any type of processor or digital calculating device or computer having

correspondingly necessary peripherals (memory, input/output interfaces, input/output devices, etc.). The processing unit can be part of a control unit of the rail vehicle or of the track monitoring system.

The above-described characteristics, features and advantages of this invention, as well as the manner in which these are realized, will become clearer and more readily understandable in connection with the following description of exemplary embodiments which are explained in more detail with reference to the schematic drawings. For clarity of illustration reasons, like or like-acting elements may be labeled therein with the same reference signs.

In the figures:

Fig.1 shows a diagram of a movement profile to illustrate the execution sequence of an efficient operating method for a rail vehicle even after failure of a communication link to a track monitoring system;

Fig.2 shows an exemplary system configuration for controlling the rail vehicle.

Fig.1 shows a schematized diagram to illustrate the execution sequence of an efficient operating method for a rail vehicle even after failure of a communication link to a track monitoring system.

The movement profile 100 shows an exemplary portion of a section of track 101 on which a rail vehicle 130 moves (e.g. in a driverless mode of operation) in a direction of travel 140 through a tunnel 110 toward a station 120.

It should be noted here that the rail vehicle (also referred to as a "train") has at least one car, wherein the car may be a traction unit, a passenger car, a freight car or a combination of compartments or functions of that type. The traction unit has a driver's cab (also referred to as an operator control console) and can be embodied with or without drive. The traction unit may in particular be a locomotive. In the driverless mode of operation the traction unit may have an emergency control console that is arranged, for example, behind a lockable panel in the passenger area.

Also shown in Fig.1 is a speed diagram 102 tailored to the section of track 101 and representing the profile of a speed v (in [km/h]) of the rail vehicle 130 as a function of a position s (in [km]) on the section of track 101.

Fig.2 shows an exemplary system configuration 200 for the proposed control of the rail vehicle 130.

The rail vehicle 130 comprises a train control device 220 having a radio-based communication unit 225. The train control device 220 is connected via an interface 221 to a braking system 215 of the rail vehicle 130. The train control device 220 is also connected via an interface 222 to a current collector 216 which is routed in a conductor rail 240 arranged along the section of track 101.

In addition, Fig.2 shows a track monitoring system 250. The track monitoring system 250 comprises a radio-based communication unit 255 as well as an interface 251 via which a switch 261 of a traction current system 260 can be actuated. The conductor rail 240 can be coupled to the traction current

system 260 via the switch 261, thus enabling electrical energy required for the operation of the rail vehicle 130 to be provided.

The track monitoring system 250 is connected via a further interface 252 to a station monitoring system 270. The station monitoring system 270 is responsible for monitoring e.g. conditions on the station side, such as components and functions (e.g. the status of doors) of a station.

One or more track sensors 275 (e.g. track monitoring sensors) optionally arranged along the section of track 101 can be connected via at least one further optional interface 253 of the track monitoring system 250 in order to register trackside states and e.g. allow inferences to be made in respect of a correct functioning of trackside components. Alternatively or in addition, trackside states can be registered or determined directly by the track monitoring system 250.

Accordingly, a line 280 symbolically separates the station from the rest of the track, i.e. the station is located logically to the left of the line 280, and the track outside of the station is to the right of the line. The track sensors 275 thus supply data relating to the track outside of the station and the station monitoring system 270 supplies data relating to the station to the track monitoring system 250.

Information (e.g. position and status information) can be exchanged between the rail vehicle 130 and the track monitoring system 250 over a wireless communication link 217 (radio link) configured by means of the communication units 225, 255.

Principle of operation:

Initially, let a normal mode of operation or fault-free operation of the rail vehicle 130 be assumed in which all trackside conditions and onboard conditions on the rail vehicle side are fulfilled, i.e. trackside and rail-vehicle onboard systems or components necessary for the operation of the rail vehicle 130 are active and required functions are available. In the normal mode of operation, the rail vehicle 130 travels at a predefined speed (the speed profile in the normal mode of operation is illustrated by means of a curve 160 in the speed diagram 102) toward the next station 120, the position and status of the rail vehicle 130 being transmitted to the track monitoring system 250 via the wireless communication link 217. In the normal mode of operation, the rail vehicle 130 is assigned a valid track warrant or "movement authority" 165 (MA) until it comes to a halt in the station 120. If the station 120 is ready for the arrival of the rail vehicle 130, this is indicated to the track monitoring system 250 by the station monitoring system 270. The switch 261 is or remains closed, the conductor rail 240 and hence the rail vehicle 130 are supplied with energy by the traction current system 260, and the rail vehicle 130 is able to drive into the station 120. The rail vehicle 130 is braked in the station 120 in accordance with the profile of the curve 160 and comes to a standstill at the designated position.

As regards the following remarks, let it be assumed that the communication link 217 between the track monitoring system 250 and the rail vehicle 130 is interrupted for example by a technical fault. Such an interruption 170 to the communication link 217 is indicated in Fig.1 while the rail vehicle 130 is traveling in the tunnel 110. In this case the interruption 170

to the communication link 217 is identified both on the part of the track monitoring system 250 and by the train control device 220 arranged in the rail vehicle 130.

If such an interruption 170 is detected, the trackside conditions, i.e. the state and the status of all trackside components and functions relevant to the current movement authority 165, are checked by the track monitoring system 250 e.g. with the aid of the track sensors 275. Within the scope of the check, either

- a status indicating the correct or fault-free functioning of all the relevant components and functions (variant A), or
- a status indicating a defective component or function (variant B)

is reported to the track monitoring system 250.

In the case of variant B, the switch 261 is opened by the track monitoring system 250, i.e. the conductor rail 240 is disconnected from the traction current system 260, and the rail vehicle 130 cannot continue in motion.

In addition, the state and the status of all onboard components and functions on the rail vehicle side are checked by the train control device 220. In particular, a check is carried out via the interface 222 to determine whether the traction current is still switched on, i.e. whether the conductor rail 240 and consequently the rail vehicle 130 are being supplied with the traction current.

An option in this case is to reduce the speed of the rail vehicle 130 to a predefined speed 167 (this is indicated by means of a curve 161 in the speed diagram 102). In this case

the rail vehicle 130 is for example assigned a limited movement authority 166 to proceed at reduced speed. Alternatively, the speed can also be reduced incrementally or in stages as a function of the distance of the rail vehicle 130 from the station 120.

If a faulty or inoperative component or function of the rail vehicle 130 is detected by the train control device 220, the movement authority 165, 166 cannot be used, even at a limited speed, up to the scheduled end. Instead, the train control device 220 initiates an immediate halting of the rail vehicle 130. Similarly, a halting of the rail vehicle 130 is also initiated if an absence of traction current is detected by the train control device 220.

In the case of variant A, it is ensured by the track monitoring system 250 that on the track side the currently assigned movement authority 165, 166 of the rail vehicle 130 can be used up to the end. In this case the track monitoring system 250 works on the assumption that the onboard states on the rail vehicle side in respect of the currently assigned movement authority 165, 166 are monitored on the part of the train control device 220 and the entry into the station 120 takes place e.g. at reduced speed.

Similarly, it is assumed by the train control device 220 onboard the rail vehicle 130 that in the case of the interruption 170 also, the trackside states, optionally based on the reduced speed of the rail vehicle 130, are monitored by the track monitoring system 250. In particular, the train control device 220 works on the assumption that if anomalous trackside states are detected by the track monitoring system 250, the switch 261 will be opened, the traction current

system 260 will be disconnected from the conductor rail 240, and consequently the traction current for the rail vehicle 130 will be switched off. In other words: As long as an activated traction current is detected at the interface 222, the rail vehicle 130 will continue to proceed up to the end of the currently assigned movement authority 165, 166, possibly at reduced speed, even if the interruption 170 is present.

If the track monitoring system 250 detects an anomalous trackside state according to variant B, which does not authorize or prohibits continued movement of the rail vehicle 130, even at an optionally reduced speed, the traction current system 260 is disconnected from the conductor rail 240 by the track monitoring system 250 by means of corresponding actuation of the current switch 261 and the traction current is switched off as a result. The switching-off of the traction current is registered on the part of the train control device 220 by readout of the interface 222 and a braking action, e.g. an immediate automatic emergency braking of the rail vehicle 130, is initiated. Accordingly, a safe state is achieved even if the interruption 170 is present. The passengers can exit the rail vehicle 130 after the latter has come to a standstill.

The solution proposed here therefore enables a continuation of movement - dependent on the correct trackside state and the correct onboard state on the vehicle side - even in the event of interruption 170 to the communication link 217 between the rail vehicle 130 and the track monitoring system 250.

Preferably such a continued movement takes place at least partially at reduced speed. If an undesirable state is detected by the track monitoring system 250, the power supply to the rail vehicle 130 is interrupted, the rail vehicle 130

detects this and brakes until it comes to a standstill. If an undesirable state is detected by the rail vehicle, it brakes autonomously (preferably until it comes to a standstill).

It is of advantage in this case that an entry into the next station is still possible even in the event of interruption 170 to the communication link. As a result there is no immediate shutdown of train operation merely due to such an interruption 170 to the communication link and a situation is avoided in which passengers enter the track area even though there is no reason to do so and the passengers would be much safer in the rail vehicle.

The approach thus enables in particular the continuation of train operation until a safe state is reached for passengers and train operation (safe-haven principle), in particular in the event of failure of the communication link between rail vehicle and track or track monitoring system.

By using the traction current system as a failsafe, unidirectional (from the track monitoring system in the direction of the rail vehicle), secondary communication system, the track monitoring system is afforded a correspondingly reliable means of transmitting information to the rail vehicle if the trackside states no longer allow a continued movement of the rail vehicle. In this case the failsafe secondary communication system is for example embodied in such a way that precisely one information unit (also referred to as a "bit") is transmitted by means of the traction current system, on the basis of which the authority for the rail vehicle to proceed is indicated or not.

For the failsafe communication system, a reliable control contact between the track monitoring system and the traction current system or current switch is used trackside in order to ensure a reliable disconnection of the traction current in the relevant track area and thus a safe braking of the rail vehicle if a hazardous situation develops.

In addition, a reliable contact between the conductor rail and the train control device by way of the current collector is used on the rail vehicle side in order to enable the information unit transmitted on the part of the track monitoring system (e.g. traction current present or switched off) to be reliably registered.

Further advantages:

One advantage consists in train operation being able to continue even in the event of a malfunctioning communication link of a rail vehicle. It is not necessary to close the entire section of track, because there is no risk emanating from passengers potentially congregating in the track area.

Another advantage is that passengers can be evacuated under supervision at the platform of the next station. There is no need to switch off the traction current in this case, because the rail vehicle and the track monitoring system have corresponding information to the effect that the rail vehicle is stationary in a station and the passengers can open the doors only on the platform side.

It is also an advantage that no additional technical equipment is necessary for the safe entry into the station in the event of failure of the communication link. The existing contact or

connection between the track monitoring system and the traction current system as well as between the train control device and the current collector is used. Said contact and connection are preferably implemented in a failsafe manner.

It is furthermore of advantage that a continued movement of the rail vehicle takes place at reduced speed. This

- enables a faster stopping of the rail vehicle after the traction current is switched off by the track monitoring system;
- prevents a potential self-evacuation of the passengers, since a self-evacuation is possible only when the rail vehicle is at a standstill;
- leads to a gain in time allowing a new setup of the communication link to be attempted or achieved;
- leads to a gain in time allowing personnel to be delegated to the station and the possible evacuation area, so that further obstacles to train operation are prevented or kept to a minimum;
- significantly reduces the requirements in terms of the continued movement of the rail vehicle (e.g. braking distances, positioning accuracy, system response times).

Although the invention has been illustrated and described in more detail on the basis of the at least one illustrated exemplary embodiment, the invention is not limited thereto and other variations can be derived herefrom by the person skilled in the art without leaving the scope of protection of the invention.

Claims

1. A method for operating a rail vehicle (130),
 - wherein a failure of a communication link (217) between a track monitoring system (250) and the rail vehicle (130) is detected by the track monitoring system (250) and by the rail vehicle (130),
 - wherein the rail vehicle (130) continues in motion even in the event of a failed communication link (217) as long as no hazard state is identified by the track monitoring system (250) and by the rail vehicle (130).
2. The method as claimed in claim 1, wherein the rail vehicle (130) is braked if a hazard state is identified.
3. The method as claimed in one of the preceding claims, wherein a power supply (260) to the rail vehicle is interrupted (261) by the track monitoring system if the hazard state is determined by the track monitoring system.
4. The method as claimed in claim 3, wherein the rail vehicle (130) is braked if an interruption to the power supply (260) is detected by the rail vehicle (130).
5. The method as claimed in one of the preceding claims, wherein the rail vehicle (130) is braked if the hazard state is determined by the rail vehicle (130).
6. The method as claimed in one of the preceding claims, wherein the hazard state is identified by the track monitoring system (250) by means of at least one track

sensor (275) and/or by means of at least one station monitoring system (270).

7. The method as claimed in one of the preceding claims, wherein the hazard state is identified by the rail vehicle (130) by means of sensors and/or information available in the rail vehicle.
8. The method as claimed in one of the preceding claims, wherein the hazard state includes at least one of the following events:
 - a malfunction of the rail vehicle,
 - a malfunction or an obstruction on the section of track to be traveled on,
 - a malfunction of the station being approached,
 - a hazard situation in the station being approached.
9. The method as claimed in one of the preceding claims, wherein the rail vehicle (130) continues in motion even in the event of a failed communication link (217) at least partially at reduced speed as long as no hazard state is identified by the track monitoring system (250) and by the rail vehicle (130).
10. The method as claimed in one of the preceding claims, wherein the communication link (217) is a wireless communication link.
11. A rail vehicle (130) having a processing unit (220) and having a communication unit (225), wherein the processing unit (220) is configured

- to detect a failure of a communication link (217) between a track monitoring system (250) and the rail vehicle (130),
 - to allow the continued movement of the rail vehicle (130) even in the event of failure of the communication link (217) as long as no hazard state can be identified and as long as no interruption to a power supply to the rail vehicle (130) can be detected.
12. The rail vehicle as claimed in claim 11, wherein the processing unit (220) is configured to initiate a braking action on the part of the rail vehicle (130) if a hazard state can be identified or if the interruption of the power supply to the rail vehicle (130) can be detected.
13. The rail vehicle as claimed in one of claims 11 or 12, wherein the processing unit (220) is configured to allow the continued movement of the rail vehicle (130) even in the event of a failed communication link (217) at least partially at reduced speed as long as no hazard state can be identified and as long as no interruption of the power supply to the rail vehicle (130) can be detected.
14. A track monitoring system (250) having a processing unit and having a communication unit (255), wherein the processing unit is configured
- to detect a failure of a communication link (217) between the track monitoring system (250) and a rail vehicle (130),
 - to supply power to the rail vehicle (130) even in the event of a failed communication link (217) as long as no hazard state can be identified.

15. The track monitoring system as claimed in claim 14, wherein the processing unit is configured to interrupt (261) the power supply (260) to the rail vehicle (130) if a hazard state can be identified.