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(54) **SYSTEM AND METHOD FOR DETECTING BROKEN RAILS ON A RAILWAY LINE**

(57) The invention relates to a system and a method for detecting broken rails for a railway line, designed to detect the breakage by means of electrical discontinuity in at least one rail (R). The system comprises an emitting node (1), a receiving node (2), and connection means for generating an electrical circuit between both nodes (1, 2) and the section of rails (R), of up to 7km between both nodes (1,2), where into the emitting node (1) injects an alternating electrical signal. The system also comprises a detector (S) associated with each rail (R) in order to detect the alternating electrical signal through the corresponding rail (R), and control means that receive the detected signals and determine whether there is electrical discontinuity in the electrical circuit, identifying the broken rail (R). In the event of double-track railway lines, the broken rail (R) is also identified and the break area is estimated.

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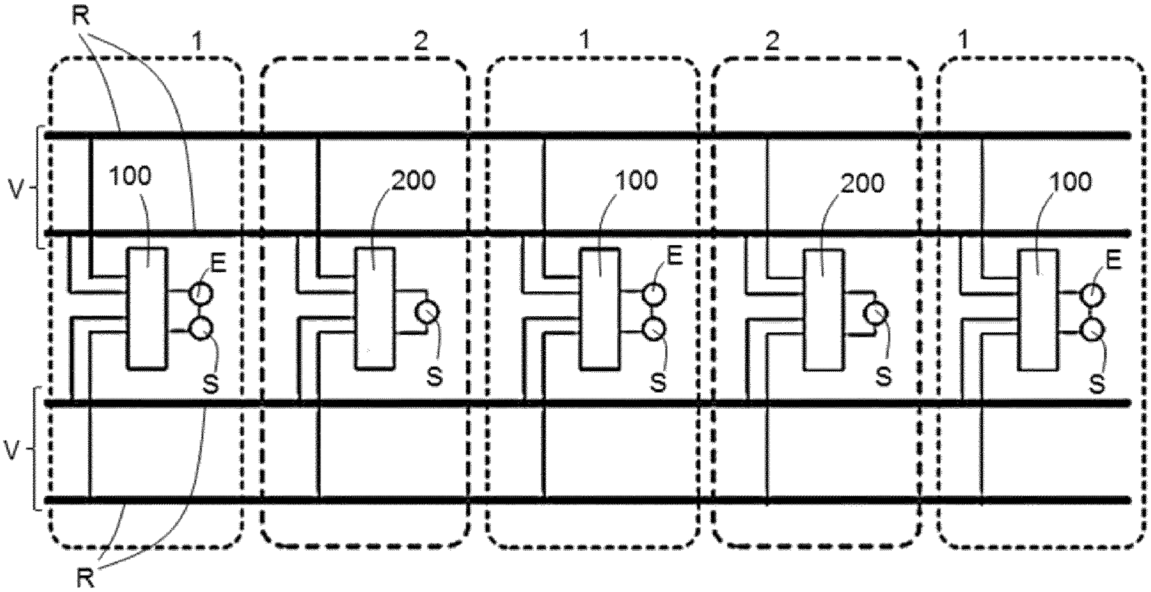

Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to systems and methods for detecting broken rails on railway lines, and more specifically to non-onboard (or track-installed) systems and methods for non-onboard systems.

PRIOR ART

[0002] Nowadays there are different technologies for detecting whether a rail which is part of a railway line is broken. Some of them are technologies applicable to onboard systems, whereas others are aimed at non-onboard systems.

[0003] Patent document US2004172216A1 discloses a non-onboard system with ultrasound technology. The system comprises one generator per rail, and the generators emit a corresponding ultrasonic signal. Respective receivers are arranged a certain distance from the rails (one per rail). The rail itself (if it is not broken) is responsible for transmitting the ultrasound from the emitting point to the receiving point, such that if a receiver does not receive a signal when it should, the breakage of the corresponding rail is determined. The advantage of this solution lies in the capacity of detecting all kinds of defects (surface damage, crack and breakage) that would affect the quality of the received signal, but it has the short range of the signal source (close to 2 meters) as a drawback, and therefore the need to incorporate a large number of repeaters, making the entire system more expensive.

[0004] Another technology used in non-onboard systems of this type is optical fiber technology. The most widespread technological solution using optical fiber consists of placing a light conductor against each rail. The main advantage is the minimum and simple infrastructure required, but its weak point is the strong mechanical stress the rail must endure for the fiber to break and for the corresponding failure to be detected.

[0005] Another technology used in non-onboard systems of this type is inductive coupling technology. The basic idea of this technology is to use the good electromagnetic conducting behavior of the rails to close a circuit in which the induced signal source is applied to a coil connected to the rails at a specific point of the railway line. A looped cable acting as a receiver is placed at a certain distance, capturing the induction propagated by the rails if they are in the correct state. The breakage of one of the rails causes an induced signal loss in the receiving loop. The main advantage thereof is the simplicity and low cost, however induced signal losses increase with distance, so for detection at large distances, the technology requires increasing the current generating electromagnetic induction or increasing the number of emitting coils and receiving loops. On the other hand, the received signal loss is indicative of a broken track but does not allow distinguishing which of the two rails has been rendered inoperative.

[0006] Another technology used in non-onboard systems of this type is elastic wave-based technology. It uses sonic and ultrasonic waves emitted by the train itself and propagated along the track where receiving devices are located. The main advantage of this technology is that it does not require additional signal sources, however the use thereof is limited by the excessive damping these signals undergo with the frequency and with the distance, making it necessary to place receivers every few meters.

[0007] Patent document ES2320517A1 discloses a technology known as "track circuit", the function of which is to detect the presence/absence of a train in a section of a railway line using the forced short-circuit between the rails of the track by means of the wheel-axle-wheel assembly of a train. Indirectly, in the absence of a train these circuits can detect whether or not there is an electrical discontinuity of the rails in the section under study, being able to determine the breakage of a rail if a discontinuity is detected. However, the exclusive use thereof as a rail breakage detector entails choosing an oversized solution with costly implementation and maintenance.

DISCLOSURE OF THE INVENTION

[0008] An object of the invention is to provide a system for detecting broken rails of a railway line, as described below.

[0009] The system of the invention is adapted for detecting broken rails by means of electrical discontinuity thereof, and comprises at least one emitting node, at least one receiving node and connection means for generating at least one electrical circuit determined between both nodes and the section of rails between both nodes, determining whether or not there is an electrical discontinuity in said section, the emitting node being configured for injecting at least one alternating electrical signal of a specific power into the electrical circuit. The system further comprises, in each of the nodes, a detector associated with each rail in the section of rails which is part of the electrical circuit for detecting the signal going through the corresponding rail as a response to the injection performed by the emitting node, and at least control means which are communicated with the detectors for receiving signals detected by said detectors and configured for determining whether there is an electrical discontinuity in the electrical circuit based on the received detections, and for determining the breakage of at least one of the rails which is part of said electrical circuit given the presence of an electrical discontinuity in said electrical circuit (particularly a breakage in the section of said rail which is part of said electrical circuit).

[0010] Another object of the invention is to provide a method for detecting broken rails on a railway line having at least one track, as described below.

[0011] With the method of the invention, at least one electrical circuit is configured between an emitting node, a receiving node and a section of rails between both nodes, at least one alternating electrical signal of a specific power is injected into the electrical circuit from the emitting node, the alternating electrical signal going through each rail which is part of the electrical circuit is detected in each of the nodes as a response to the injected alternating electrical signal, and it is determined whether there is an electrical discontinuity in a rail which is part of the electrical circuit, within the section which is part of said electrical circuit, and therefore whether there is a breakage in said rail, depending on said detected signals.

[0012] Therefore, both the system and method of the invention make it possible to place the receiving node and the emitting node at great distances from one another in comparison with known prior art solutions, since the injection of an alternating signal on at least one rail with a suitable power is made possible, the excitation voltage value and the current value of said alternating signal being limited by electrical safety restrictions inherent to railway systems (maximum excitation voltage: 30 V; maximum current: 5A). Particularly, distances between the different technical buildings distributed along railway lines (which are separated from one another by distances between about 10 km and 14 km) can be covered with a smaller number of devices given that the emitting nodes can be placed in the technical buildings and the receiving nodes can be place at intermediate points with respect to said technical buildings (intermediate points which can be at about between 5 km and 7 km from the technical buildings), for example. The number of installations required for detecting breakages on railway lines therefore significant decreases, with both the technical and economic advantages this entails. Sub-stations, autotransformers, communication cassettes, transformation centers, etc., must be included in the definition of a technical building.

[0013] These and other advantages and features of the invention will become evident in view of the drawings and detailed description of the invention.

DESCRIPTION OF THE DRAWINGS

[0014]

Figure 1 schematically shows an overall structure of an embodiment of the system of the invention.

Figure 2 schematically shows two independent circuits configured with the system of the invention for two tracks of a double-track railway line.

Figure 3 schematically shows an electrical circuit configured with the system of the invention, for joint excitation of both tracks of a double-track railway line.

Figure 4 shows the electrical circuit of Figure 3, with a breakage in each rail and where the coupling impedances between rails are depicted.

Figure 5 schematically shows an electronic structure of the system of Figure 1.

DETAILED DISCLOSURE OF THE INVENTION

[0015] A first aspect of the invention relates to a system for detecting broken rails on a railway line comprising at least one track V with two parallel rails R, which is preferably also adapted for detecting broken rails on a double-track railway line as schematically and structurally shown in Figure 1, for example. The system is designed so that the breakage in any rail R is detected based on the detection of an electrical discontinuity given that the capacity of the rails R themselves is used as electricity conductors. The system of the invention is furthermore a non-onboard system, i.e., it is installed on the track or in the surrounding area, and a train or vehicle running on the tracks is not part of said system.

[0016] The system comprises at least one emitting node 1, at least one receiving node 2 arranged at a specific separation distance from the emitting node 1, and connection means for generating at least one electrical circuit determined between both nodes 1 and 2 and the section of rails R of the railway line between both nodes 1 and 2. The connection means allow electrical connection of the nodes 1 and 2, respectively, to the different rails R, such that it is possible to generate an electrical circuit between both nodes 1 and 2 and the section of rails R between both nodes 1 and 2, thus being able to detect whether there is a breakage in a rail R within said section of rails R based on whether the configured electrical circuit is closed (there is no electrical discontinuity in any of the sections of the rails R which are part of the electrical circuit) or open (there is at least one electrical discontinuity in one of the sections of rails R which are part of the electrical circuit). To that end, the emitting node 1 is configured for injecting at least one alternating electrical signal of a specific power into the electrical circuit (for the sake of clarity, the generation is depicted with reference E in the drawings), determining whether or not there is a discontinuity in one of the rails R which are part of the corresponding electrical circuit depending on said injected signal.

[0017] The signal which is injected has specific electrical properties and the length of the section of rails R which can be inspected depends on said properties. The injection of an alternating electrical signal must be interpreted as the generation of an alternating voltage (excitation voltage) which is applied to the electrical circuit providing a specific current.

[0018] The system comprises in each of the nodes 1 and 2 a detector S associated with each rail R, in the section of rails R which is part of the electrical circuit (see Figures 2 and 3), for detecting the signal going through the corresponding rail R as a response to the injection performed by the emitting node 1, and at least control means which are communicated with the detectors S for receiving signals detected by said detectors S and configured for determining whether there is an electrical discontinuity in the electrical circuit based on said signals, and for determining the breakage of at least one of the rails R (and of which rail R) which is part of said electrical circuit, in the section of rails R object of the study, given the presence of an electrical discontinuity in said electrical circuit.

[0019] The characteristics of the injected alternating electrical signal and the impedance of the electrical circuit are known, so the characteristics of the signals to be detected by the detectors S as a response to the injected alternating electrical signal can be anticipated. The control means can therefore determine whether or not the received signals correspond with the expected ones, thus being able to determine whether or not there is a discontinuity in said section of rails R. Furthermore, due at least to the presence of a coupling impedance Zrr between two rails R of one and the same track V and to the plurality of detectors S used, the control means are furthermore configured for determining the rail R in which electrical discontinuity has occurred based on the received signals.

[0020] Generating an electrical circuit between an emitting node 1, a receiving node 2 and the section of rails R between said nodes 1 and 2 of a railway line, and injecting an alternating electrical signal of a specific frequency into said electrical circuit allow placing the emitting node 1 and the receiving node 2 at greater distances from one another than with known prior art technologies, given that the alternating electrical signal is capable of covering greater distances. There are inherent electrical restrictions in railway lines that the alternating electrical signal must also comply with (maximum excitation voltage of 30 V and maximum current of 5 A). Taking these limitations into account, an alternating electrical signal can be configured which, when injected by the emitting node 1, it is correctly received in the receiving node 2 and in the emitting node 1 itself after going through the receiving node 2, with a level that depends on whether or not there is breakage in a rail R, the separation between the nodes 1 and 2 being able to be up to at least 10 km as a result of the system of the invention. Furthermore, it must be taken into account that the section of railway line excited with the injected signal and analyzed comprises the distance between the two contiguous receiving nodes 2 thereof (Figure 1), so the distance of railway line evaluated with one and the same emitting node 1 can reach 20 km (10 km on each side of the emitting node). To calculate the distance that can be covered by the alternating electrical signal, the characteristics of the alternating electrical signal itself and the characteristics of the configured electrical circuit (impedance, for example) must be considered, but this calculation is not provided in detail given that based on these premises a person skilled in the art would know the limits of the generated electrical signal. The system of the invention therefore allows placing the emitting nodes 1 in technical buildings present along railway lines and placing the receiving nodes 2 at an intermediate point between two technical buildings (between two emitting nodes 1), such that there is a separation distance of between about 5 km and 9 km between nodes 1 and 2. Sub-stations, autotransformers, communication cassettes, transformation centers or installations which are present along railway lines and separated from one another by between 10 km and 14 km in general must be included in the definition of a technical building.

[0021] The system comprises respective control means 11 and 21 in each node 1 and 2 that receive the signals detected by the respective detectors S (control means 11 receive signals from the detectors S of the emitting node 1 and control means 21 receive signals from the detectors S of the receiving node 2), and a data communication line 3 through which both control means 11 and 21 are communicated to one another. Preferably the communication line 3 corresponds with the line existing in the railway lines, the addition of an additional communication line being unnecessary (it could be added if no such line exist). The communication line 3 can be an Ethernet line, for example, although it could also be of another type.

[0022] Preferably, the control means 21 of the receiving node 2 are configured for sending the signals they receive to the control means 11 of the emitting node 1, and said control means 11 are configured for determining whether or not there is an electrical discontinuity in the electrical circuit depending on the signals received from the receiving node 2 through the communication line 3 and on the signals received from the detectors S of the emitting node 1 itself, said control means 11 being those which determine whether or not there is breakage in a rail R, and where appropriate, which rail R is broken. Alternatively, the control means 21 of the receiving node 2 may be the ones responsible for performing determinations, the emitting node 1 sending the received signals to the receiving node 2 through the communication line 3. Therefore, only one of the control means 11 and 21 is required to have the computing capabilities for determining whether or not a rail R is broken.

[0023] The system is adapted for configuring different electrical circuits between an emitting node 1, a receiving node 2 and the section of rails R between both nodes 1 and 2. To that end, the connection means comprise a first module 100 in the emitting node 1 through which said emitting node 1 can be electrically connected in different ways to the rails R of a railway line, and a second module 200 in the receiving node 2 through which said receiving node 2 can be electrically connected in different ways to the rails R of a railway line. Each module 100 and 200 comprises at least one controllable switch (not depicted in the drawings) for each rail R, both nodes 1 and 2 thus being able to be electrically connected to all the rails R of the railway line, and each of the control means 11 and 21 is communicated with the corresponding module 100 and 200 and configured for controlling the opening and closing of said switches for configuring the different electrical circuits between the nodes 1 and 2 and the section of rails R between both nodes 1 and 2. The two control means 11 and 21 are furthermore configured for controlling the switches of the modules 100 and 200, respectively, in a coordinated manner, such that they cooperate with one another for configuring the required electrical circuit between both nodes 1 and 2 and the section of rails R between both nodes 1 and 2.

[0024] The first module 100 is adapted for associating the emitting node 1 with two receiving nodes 2, one on each side (one on the right side and the other on the left side thereof, as shown in Figure 1, for example), and the second module 200 is adapted for associating the receiving node 2 with two emitting nodes 1, one on each side (one on the right side and the other on the left side thereof), the control means 11 of the emitting node 1 and the control means 21 of both receiving nodes 2 being configured for controlling the respective modules 100 and 200 in a coordinated manner. This thereby allows duplicating the evaluated section of rails R of the railway line with one and the same emitting node 1, with the advantages that this entails in terms of cost, installation and maintenance, for example.

[0025] The control means 11 and 21 allow configuring an electrical circuit between the emitting node 1, the receiving node 2 and the section of rails R between both nodes 1 and 2 of a track V of the railway line. Two independent electrical circuits can therefore be configured for the case of a double-track railway line, one for each track V, as shown by way of example in Figure 2. For the case of a double-track railway line, the emitting node 1 is configured so that it preferably injects a first signal into the electrical circuit of one track V and then injects another signal into the electrical circuit of the other track V.

[0026] For the case of a double-track railway line, the control means 11 and 21 and modules 100 and 200 are adapted and configured to be able to furthermore configure another electrical circuit involving both tracks V between the emitting node 1, the receiving node 2 and the section of rails R of both tracks V which is between both nodes 1 and 2, the electrical circuit between the four rails R (the section) forming the railway line thus being configured as shown by way of example in Figure 3. In this case, the emitting node 1 would inject an alternating electrical signal into both rails R of one and the same track V, the circuit through the receiving node 2 and the rails R of the other track V being closed. In said electrical circuit, the emitting node 1 is connected to both tracks V of the railway line and in the receiving node 2 the four rails R are short-circuited. This new configuration allows the control means 11 to be able to identify the broken rail R and estimate the break area of said rail R.

[0027] Referring to Figure 3, in the emitting node 1 the system can comprise a first signal bar 17 acting as a node for separating the alternating electrical signal into two (one for each of the rails R), such that the generation of a single alternating electrical signal is sufficient for the electrical circuit. To close the corresponding electrical circuit, the system further comprises a second signal bar 18 unifying the two signals arriving from the two rails of the other track V (second track V). The detectors S of the emitting node 1 are arranged between the rails R and the signal bars 17 and 18.

[0028] In the receiving node 2, the system in turn comprises two signal bars 27 and 28. The first signal bar 27 unifies the two signals arriving from the two rails R of the first track V, and the second signal bar 28 separates the alternating electrical signal it receives from the first signal bar 27 into two, one for each rail R of the second track V. Like in the emitting node 1, in the receiving node 2 the detectors S are arranged between the rails R and the signal bars 27 and 28.

[0029] A detector S detects an alternating electrical signal associated with its corresponding rail R as a response to the injected alternating electrical signal. Preferably, the detector S comprises a sense resistor detecting the current going through said rail R at that point, although a different detector S could be used. Therefore, based on the relative differences (of one detector S with respect to others) between the current (or voltage, for example) levels, which are indicative of one or more electrical discontinuities in the analyzed electrical circuit, the presence of at least one broken rail R in the analyzed section of track V (section which is part of said electrical circuit) can be detected.

[0030] The emitting node 1 is configured for generating the alternating electrical signal based on a digital carrier signal which is modulated by means of a specific code. The frequency of the carrier signal is selected so that its bandwidth is not affected by the network frequency (50 Hz) and its main harmonics, so a frequency of at least 500 Hz is selected. On the other hand, the protection systems used today in railway lines use signals having a frequency above 1 kHz, and further taking into account that the damping of an emitted signal increases with frequency, the selected frequency is below 1 kHz. The bandwidth of the modulated digital signal is therefore comprised in the range defined between 500 Hz and 1 kHz, and preferably between about 700 Hz and about 900 Hz (which results in a carrier digital signal frequency of about 800 Hz).

[0031] The coding used contributes to the detection of signals with a high immunity to surrounding noise. The modulation used allows concentrating the energy of the signal in the required bandwidth. Preferably, BPSK modulation with a 1023-bit Kasami code is used, but another type of modulation and coding could be used.

[0032] The emitting node 1 comprises a digital-to-analog converter DAC for converting said modulated digital signal into a modulated analog signal (which may or may not be integrated in the control means 11) and an amplifier 19 for amplifying said modulated alternating electrical signal, said amplified signal being the alternating electrical signal which is injected. Therefore, as a result of the system of the invention an alternating electrical signal can be injected with properties with which at least the following advantages are obtained:

- The electrical discontinuity of rails R of sections of railway line can be analyzed with a large distance between an emitting node 1 and a receiving node 2 compared with the distance allowed with the systems of the prior art.
- Signals with a high electrical immunity against surrounding noises are detected.
- The signals emitted by each emitting node 1 can be distinguished such that each receiving node 2 interprets from which source (from which contiguous emitting node 1) the detected signal originates.

[0033] The system comprises in each node 1 and 2 at least one analog-to-digital converter ADC for digitizing the alternating electrical signal detected by the corresponding detectors S, the control means 11 and 21 being connected to the corresponding analog-to-digital converter ADC for receiving said digitized signals and processing them. In order to process same, the control means 11 and 21 demodulate the detected signals they receive from the corresponding detectors S, decode same and perform a correlation process with the known data pattern used for generating the alternating electrical signal itself to be injected. The control means 21 transmit the processed signals to the corresponding emitting node 1 through the communication line 3 (adapting it to the corresponding protocol, Ethernet, etc.).

[0034] The control means 11 analyze the signals received from the receiving node 2 and the signals processed in the emitting node 1 itself and determine whether or not there is breakage (and should there be one, which one is broken and the estimated break area). Alternatively, the control means 21 may not process the signals received from the detectors S (or at least part of the processing steps), in which case they would send said signals to the corresponding emitting node 1 so that this emitting node 1 is responsible for processing them (or completing the missing steps).

[0035] To achieve galvanic isolation between the railway line and the electronic components of the nodes 1 and 2 and thereby protect said electronic components against possible electromagnetic energy spikes disturbing the track(s) V of the railway line, the system further comprises:

- a transformer T1 between the amplifier 19 and each rail R into which the electrical signal in the emitting node 1 can be injected, which allows galvanically isolating the electronic components of the emitting node 1 responsible for generating the signal to be injected of the electrical circuit of which the railway line is a part, and
- a decoupling element not depicted in the drawings (preferably a transformer) for each detector S, for associating each detector S with the corresponding rail R, the current sense resistor (or the equivalent element) thus being galvanically isolated from said rail R.

[0036] On the other hand, the detected alternating signal associated with each rail R is filtered (by means of band pass filters not depicted in the drawings) both in the emitting node 1 and in the receiving node 2 in order to eliminate the frequencies outside the bandwidth of interest. The pass band of the filter is sized for the bandwidth of the signal to be injected, preferably between about 700 Hz and about 900 Hz as mentioned above. The filtered signals arrive at the corresponding analog-to-digital converter ADC.

[0037] The control means 11 and 21 can be a microprocessor, a microcontroller, a PC, a dedicated card, an FPGA or any device with computing capability to carry out the required and mentioned actions.

[0038] A second aspect of the invention relates to a method for detecting a broken rail for a railway line, whereby the breakage of the rails R is detected by means of electrical discontinuity thereof. The method is adapted for being implemented in a system such as the one mentioned for the first aspect of the invention.

[0039] In the method, at least one electrical circuit is configured between an emitting node 1, a receiving node 2 and the section of rails R between both nodes 1 and 2, at least one alternating electrical signal of a specific power is injected into the electrical circuit from the emitting node 1, the alternating electrical signal going through each rail R which is part of the electrical circuit is detected in each of the nodes 1 and 2 as a response to the injected alternating electrical signal, and it is determined whether there is an electrical discontinuity in a rail R which is part of the electrical circuit, and therefore whether there is breakage in said rail R, depending on said detected signals. The method is therefore adapted for being implemented when no rolling stock is running along the section of rails R to be analyzed (or preferably in nearby sections either to prevent sources of interference from said rolling stock).

[0040] Preferably, the signal is injected during a specific time, which can be 1 minute, for example, and the electrical signal through the rails R is detected with the corresponding detectors S during said time interval. The nodes 1 and 2 are synchronized such that the receiving node 2 performs the functions for which it is responsible (detecting signals and transmitting same through the communication line 3) provided that the emitting node 1 injects the corresponding alternating electrical signal(s), said receiving node 2 being at rest as long as the emitting node 1 does not inject any signal (the emitting node 1 is also at rest in that situation), reducing energy consumption. Synchronization can be performed in different ways, for example the emitting node 1 can be programmed to act periodically and when activated causes activation of the receiving node 2, both nodes 1 and 2 can be programmed and synchronized, or a remote controller can be responsible for activating both nodes 1 and 2.

[0041] The detected signals reach the corresponding control means 11 and 21 (filtered and digitized as explained for the first aspect of the invention), and said control means 11 and 21 process and record the signals as mentioned for the first aspect of the invention, for example. Correlation of the signals received by the control means 11 and 21 is performed during processing taking into account the data patterns used for coding the injected alternating electrical signal. The correlation results obtained in the control means 21 of the receiving node 2 are sent through the communication line 3 to the control means 11 of the emitting node 1 for joint analysis (analysis of the signals processed in the control means 21 and signals processed in the actual control means 11). The analysis allows determining whether or not there is an electrical discontinuity in the electrical circuit, and therefore whether there is breakage in a rail R, as explained also for the first aspect of the invention. Alternatively, the control means 21 may not process the signals received from the detectors S (or they may not perform at least part of the processing steps), in which cases they would send said signals to the corresponding emitting node 1 so that this emitting node 1 is responsible for processing them (or completing the missing steps).

[0042] In the case of a railway line having a single track V, the method implements a detection process from a single excitation (independent excitation process). In the process, an electrical circuit is configured between the emitting node 1, the receiving node 2 and the section of rails R between both nodes 1 and 2 of said track V of the railway line, the alternating electrical signal is injected into the electrical circuit, the electrical signal going through each of the rails R in the section of said rails R which is part of said electrical circuit is detected in each node 1 and 2, the detected signals are processed in the control means 11 and 21, and it is determined whether there is an electrical discontinuity in a rail R, and therefore whether or not there is breakage, depending on said detected electrical signals.

[0043] On a double-track railway line, the independent excitation process is implemented in both tracks V (see Figure 2). The breakage of a rail R in both tracks V can therefore be detected in the same test. If the breakage of at least one rail R in at least one of the two tracks V (in the evaluated sections, respectively) is determined as a result of both independent excitation processes, an additional detection process (joint excitation process, see Figure 3) is implemented in the method in which a joint excitation of both tracks V (of sections of tracks V which have previously been evaluated with respective independent excitation processes) is carried out.

[0044] In the additional detection process (joint excitation process), an electrical circuit is configured between the emitting node 1, the receiving node 2 and the section of rails R of both tracks V which is between the nodes 1 and 2 (see Figure 3), the emitting node 1 in said electrical circuit being connected to both tracks V and the four rails R being short-circuited in the receiving node 2, an alternating electrical signal is injected into the electrical circuit, the electrical signal going through each of the rails R which are part of the electrical circuit is detected in each node 1 and 2 and in each track V, and the detected signals are processed. The simultaneous analysis of all the detected signals (eight in total, four signals recorded by the control means 21 of the receiving node 2 and four signals recorded by the control means 11 of the emitting node 1) allows identifying the broken rail R (internal or external rail of each track V) and estimating the approximate break area (area close to the emitting node 1, close to the receiving node 2 or an intermediate area, for example).

[0045] Due to the coupling impedances Zrr existing between the rails R of one and the same track V and to the coupling impedances Zrri existing between the two adjacent rails R of the two tracks V, shown by way of example using dotted lines in Figure 4 (where breakage in each rail R is furthermore shown), the alternating electrical signals through the electrical circuit are not completely canceled out even in the event of an electrical discontinuity of a rail R (breakage). In the event of an electrical discontinuity, these coupling impedances Zrr and Zrri contribute to the amplitude (level) of the signals detected in the nodes 1 and 2 being affected. Based on these amplitude changes, the control means 11 are capable of identifying the broken rail R and estimating the approximate break area. For analyzing the signals in the control means 11, a look-up-table or equivalent listing signal amplitude data with break areas can be implemented, for example.

[0046] The explanations provided for the first aspect of the invention concerning signal generation, the detection of signals in the rails, the treatment of the detected signals and the determinations of the control means 11 and 21 are also valid for the second aspect of the invention.

Claims

1. System for detecting broken rails on a railway line having at least one track, which is adapted for detecting broken rails (R) by means of detecting an electrical discontinuity thereof, **characterized in that** the system comprises at least one emitting node (1), at least one receiving node (2) and connection means for configuring at least one electrical circuit determined between both nodes (1, 2) and the section of rails (R) between both nodes (1, 2), determining whether or not there is an electrical discontinuity in said section, the emitting node (1) being configured for injecting at least one alternating electrical signal of a specific power into the electrical circuit, the system also comprising, in each of the nodes (1, 2), a detector (S) associated with each rail (R) in the section of rails (R) which is part of the electrical cir-

cuit, for detecting the signal going through the corresponding rail (R) as a response to the injection performed by the emitting node (1), and at least control means (11, 21) which are connected to the detectors (S) for receiving signals detected by said detectors (S) and configured for detecting whether there is an electrical discontinuity in the electrical circuit based on the signals received from the detectors (S), and for determining the breakage of at least one of the rails (R) which is part of said electrical circuit in said section given the presence of an electrical discontinuity in said electrical circuit.

2. System according to claim 1, comprising respective control means (11, 21) in each node (1, 2) that receive the signals detected by the detectors (S) of the corresponding node (1, 2) thereof, and a data communication line (3) through which the control means (11) of the emitting node (1) and the control means (21) of the receiving node (2) which are part of one and the same electrical circuit are communicated to one another, at least one of said control means (11, 21) being configured for transmitting the signals detected by the detectors (S) corresponding to the control means (11, 21) of the other node (1, 2) through the communication line (3), and the control means (11, 21) receiving the signals through the communication line (3) being configured for determining whether there is an electrical discontinuity in the corresponding electrical circuit depending on said signals and on the signals detected by the detectors (S) of the node (1, 2) thereof.

3. System according to claims 1 or 2, wherein the connection means comprise a first module (100) in the emitting node (1) through which said emitting node (1) can be electrically connected in different ways to the rails (R), and a second module (200) in the receiving node (2) through which said receiving node (2) can be electrically connected in different ways to the rails (R), different electrical circuits thus being able to be configured between the nodes (1, 2) and the section of rails (R) between both nodes (1, 2), each of the control means (11, 21) being connected to the module (100, 200) corresponding to the node (1, 2) thereof for controlling same, both control means (11, 21) being configured for controlling the respective modules (100, 200) in a coordinated manner.

4. System according to claim 3, wherein the first module (100) is adapted for associating the emitting node (1) with two receiving nodes (2), one on the right side and the other on the left side thereof, and the second module (200) is adapted for associating the receiving node (2) with two emitting nodes (1), one on the right side and the other on the left side thereof, the control means (11) of the emitting node (1) and the control means (21) of both receiving nodes (2) being configured for controlling the respective modules (100, 200) in a coordinated manner.

5. System according to claim 3 or 4, wherein the control means (11, 21) and modules (100, 200) are adapted and configured for configuring, between an emitting node (1) and a receiving node (2), an electrical circuit between said emitting node (1), said receiving node (2) and the section of rails (R) between both nodes (1, 2) of a track (V) of the railway line.

6. System according to any of claims 3 to 5, wherein the control means (11, 21) and the connection means (100, 200) are adapted and configured for configuring, between an emitting node (1) and a receiving node (2), an electrical circuit involving the two tracks (V) of a double-track railway line, said electrical circuit being configured between said emitting node (1), said receiving node (2) and the section of rails (R) of both tracks (V) which is between the nodes (1, 2), the emitting node (1) in said electrical circuit being connected to both tracks (V) and the four rails (R) being short-circuited in the receiving node (2).

7. System according to any of claims 1 to 6, wherein each detector (S), both of the emitting node (1) and of the receiving node (2), comprises a sense resistor, the system further comprising for each detector (S) a decoupling element for associating each detector (S) with the corresponding rail (R), a band pass filter and an analog-to-digital converter (ADC).

8. System according to any of claims 1 to 7, wherein the emitting node (1) is configured for generating the alternating electrical signal to be injected from a carrier signal which is modulated by means of a specific code and a specific modulation and comprises a digital-to-analog converter (DAC) for converting said modulated digital signal into a modulated analog signal, and an amplifier (19) for amplifying said modulated alternating electrical signal to the required power, said amplified signal being the alternating electrical signal which is injected.

9. System according to any of claims 1 to 8, wherein the emitting node (1) comprises a transformer (T1) between the amplifier (19) and each rail (R) on which the alternating electrical signal can be injected.

10. Method for detecting broken rails on a railway line having at least one track, **characterized in that** at least one electrical circuit is configured between an emitting node (1), a receiving node (2) and a section of rails (R) between both nodes (1, 2), at least one alternating electrical signal of a specific power is injected into the electrical circuit from the emitting node

(1), the alternating electrical signal going through each rail (R) which is part of the electrical circuit is detected in each of the nodes (1, 2) as a response to the injected alternating electrical signal, and it is determined whether there is an electrical discontinuity in a rail (R) which is part of the electrical circuit, and therefore whether there is a breakage in said rail (R), depending on said detected signals.

11. Method according to claim 10, wherein the signals detected in one of the nodes (1, 2) as a response to the injection of the alternating electrical signal into the corresponding electrical circuit are transmitted to the other node (1, 2) through a communication line (3), determining whether there is an electrical discontinuity in said electrical circuit in the node (1,2) that receives the signals through the communication line (3) depending on the signals received through the communication line (3) and on the signals detected through the rails (R) associated with said node (1, 2).

12. Method according to claim 10 or 11, wherein a detection process is carried out in at least one track (V) of the railway line in which an electrical circuit is configured between the emitting node (1), the receiving node (2) and the section of rails (R) between both nodes (1, 2) of said track (V) of the railway line, the alternating electrical signal is injected into one of the rails (R) which are part of said electrical circuit, the electrical signal going through each of the rails (R) which are part of said electrical circuit is detected in each node (1, 2), and depending on said detected electrical signals, it is determined whether there is an electrical discontinuity in a rail (R) which is part of the electrical circuit, and therefore whether there is a breakage in said rail (R), depending on said detected signals.

13. Method according to claim 12, wherein a detection process is carried out for each track (V) in a double-track railway line, both processes being independent of one another, and if breakage of a rail (R) is detected in either of the two tracks (V), an additional detection process is carried out in which an electrical circuit is configured between the emitting node (1), the receiving node (2) and the section of rails (R) of both tracks (V) which is between the nodes (1, 2) and which have been evaluated with the independent detection process, the emitting node (1) in said electrical circuit being connected to both tracks (V) and the four rails (R) being short-circuited in the receiving node (2), an alternating electrical signal is injected into the electrical circuit, the electrical signal going through each of the rails (R) which are part of the electrical circuit is detected in each node (1, 2), and depending on said detected signals, the rail (R) in which electrical discontinuity occurs is determined and the break area in said rail (R) is estimated.

14. Method according to any of claims 11 to 13, wherein the alternating electrical signal to be injected is generated based on a carrier signal which is modulated by means of a specific code and a specific modulation, the modulated digital signal is converted into a modulated analog signal, and said modulated analog signal is amplified, said amplified signal being the alternating electrical signal which is injected.

15. Method according to claim 14, wherein the bandwidth of the carrier signal is within a frequency range defined between about 500 Hz and about 1 kHz, preferably between about 700 Hz and about 900 Hz.

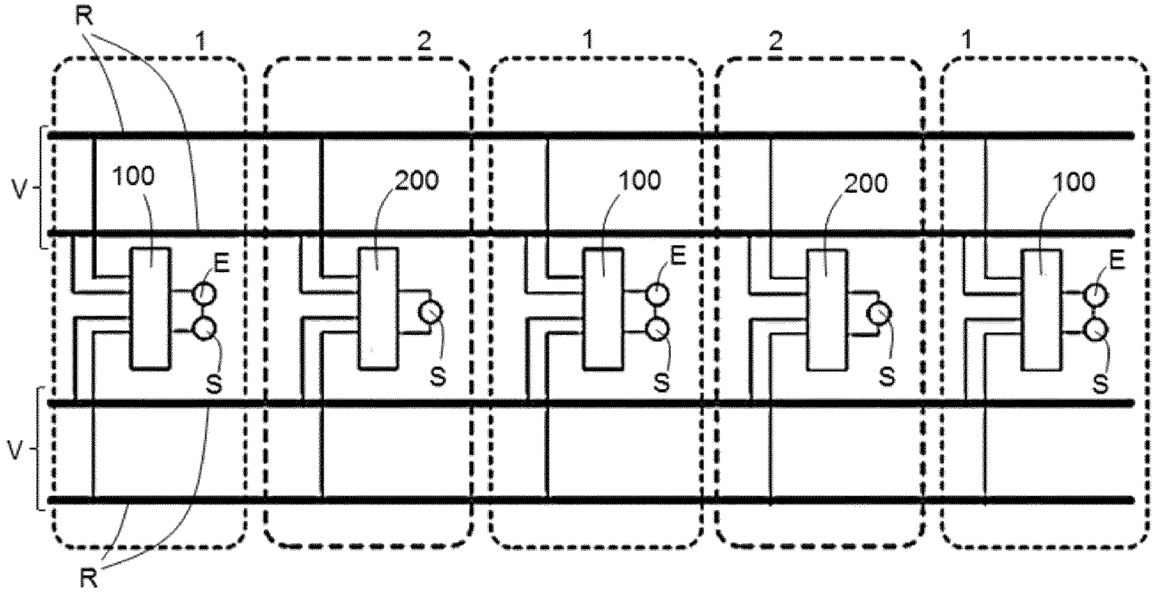

Fig. 1

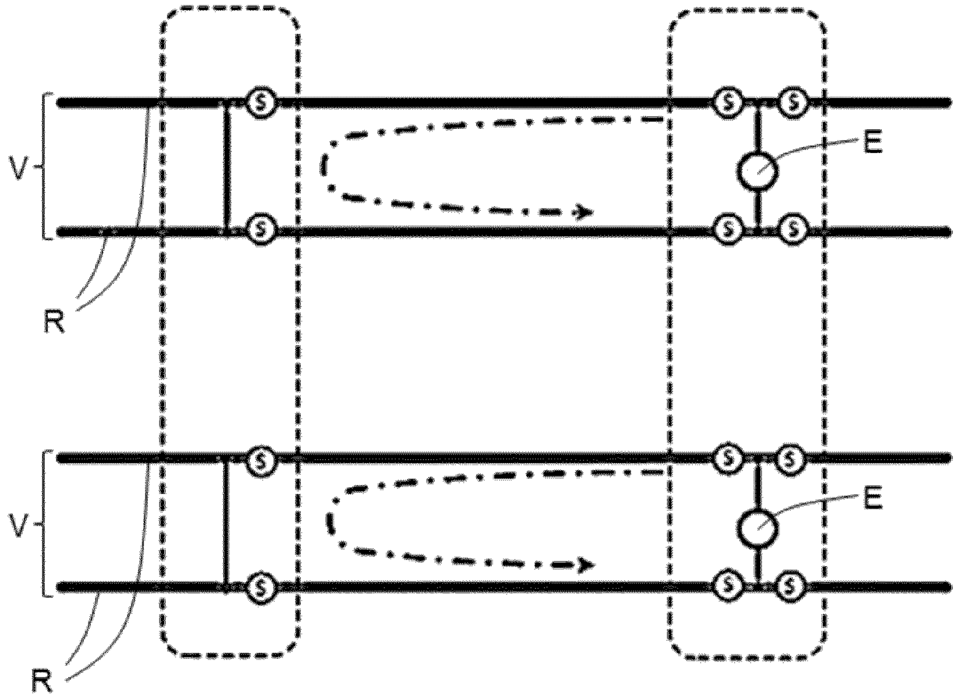

Fig. 2

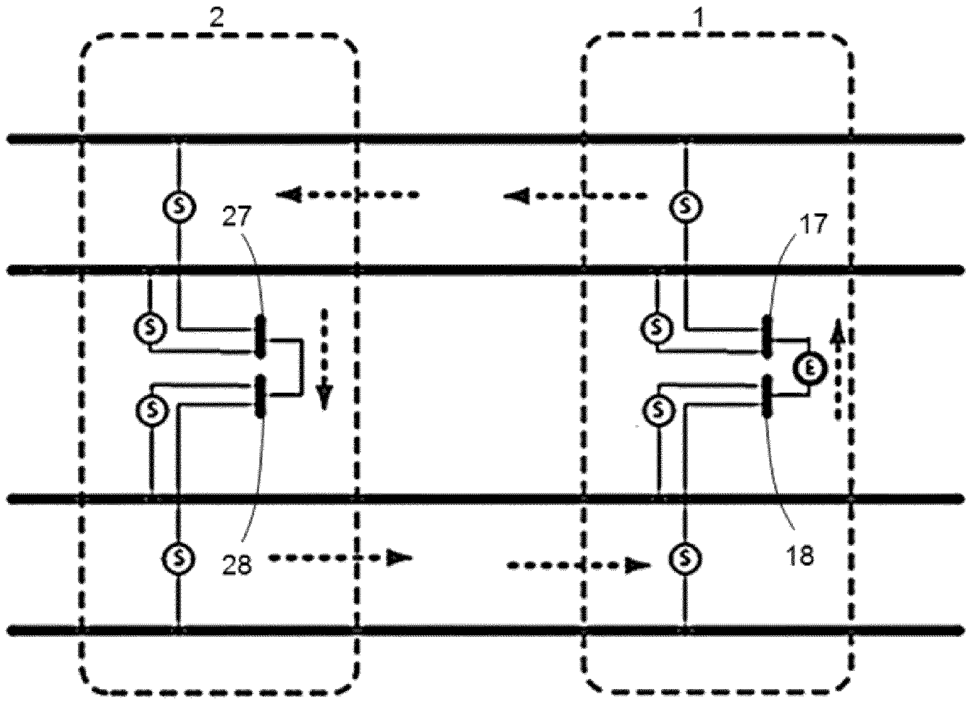

Fig. 3

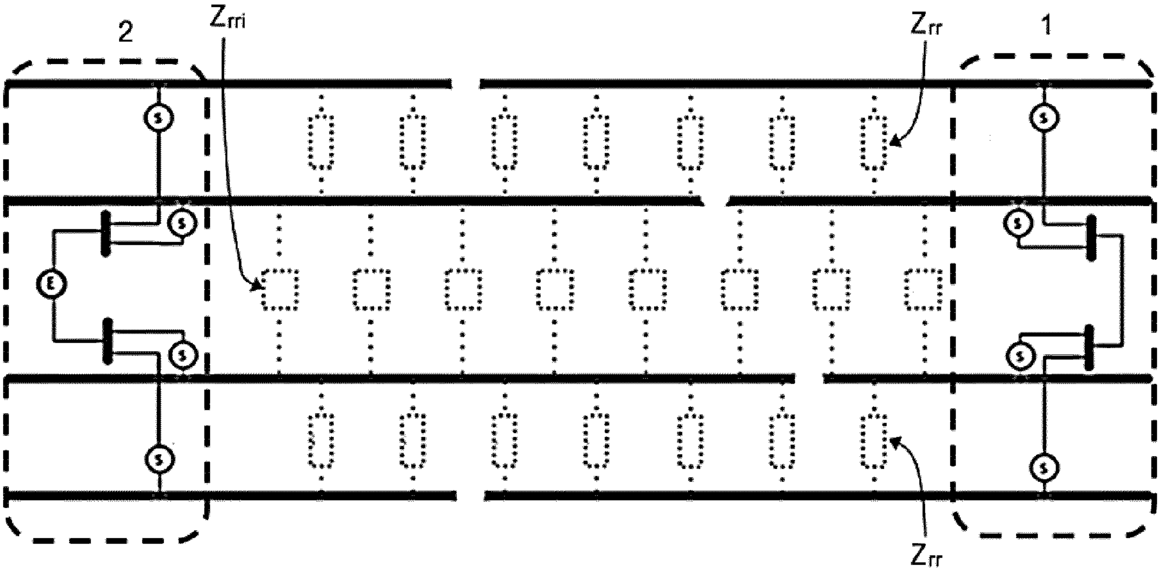

Fig. 4

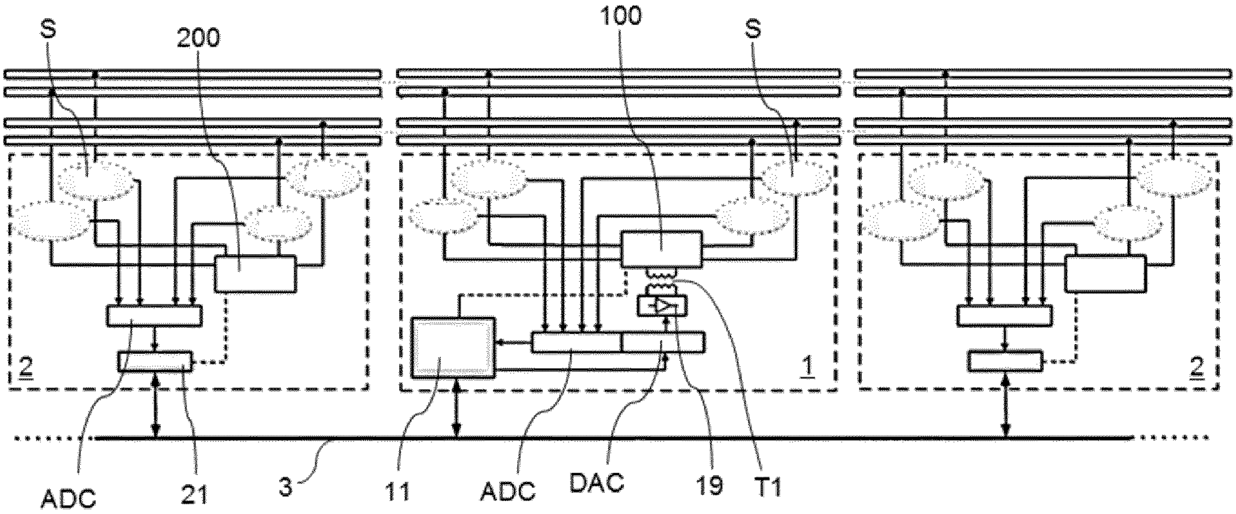

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES2015/070656

A. CLASSIFICATION OF SUBJECT MATTER

B61L23/04 (2006.01)
B61K9/10 (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61L, B61K, G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, INVENES, Internet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	FR 2758301 A1 (COGIFER) 17/07/1998, the whole document.	1-5,7-12,14,15 6,13
Y A	FR 2758302 A1 (COGIFER) 17/07/1998, description; figures.	6,13 1-5,7-12,14,15
A	Wikipedia "Resistors" 29.09.2011; Retrieved from Internet 09.12.2015; https://web.archive.org/web/20110929220410/ http://in.wikipedia.org/wiki/Resistor#Ammeter_shunts	1,7

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09/12/2015	**(11/12/2015)**
Name and mailing address of the ISA/ OFICINA ESPAÑOLA DE PATENTES Y MARCAS Paseo de la Castellana, 75 - 28071 Madrid (España) Facsimile No.: 91 349 53 04	Authorized officer M. López Sábater Telephone No. 91 3495385

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/ES2015/070656

Patent document cited in the search report	Publication date	Patent family member(s)	Publication date
FR2758301 A1	17.07.1998	NONE	
FR2758302 A1	17.07.1998	NONE	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2004172216 A1 **[0003]**
- ES 2320517 A1 **[0007]**