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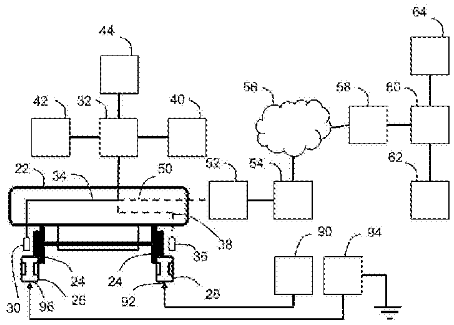
(54) **Monitoring of electric railway systems.**

(57) In a system and method for monitoring an electric railway system track, at least one magnetic field sensor is provided, which is configured to sense values of a magnetic field parameter. The magnetic field sensor is moved along the track, and senses magnetic field parameter values at sensing locations along the track. The sensed magnetic field parameter values are processed to determine a condition of the track. The magnetic field sensor is mounted on a vehicle configured for displacement along the track. The vehicle is moved along the track. A current may be fed into a track rail, or a voltage may be applied between a track rail and earth, for a current to flow through the track rail.



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Monitoring of electric railway systems

FIELD

The present disclosure relates to the field of electric railway systems, and specifically to monitoring of electric railway systems. More specifically, the invention relates to methods and systems for detecting stray currents in electric railway systems.

BACKGROUND OF THE INVENTION

In electric railway systems, whether DC or AC powered, it is important to monitor a condition of the track. When the track is viewed from an electrical performance point of view, it is primarily part of a power supply circuit for a train on the track. Power is supplied from substations to a train via an overhead line or via a third rail. A circuit is formed between the power supplying line, the train, and the track rails, wherein the track rails provide a return path for the current. When the track is viewed from a mechanical performance point of view, it must primarily be able to support a train and guide the wheels of the train at the prevailing speed.

When taking into account the electrical performance of the track, the electrical circuit of which the track rails form part may not be completely isolated from the underground and is therefore susceptible to electromagnetic fields induced by natural or manmade structures in the periphery of the tracks. Because the return path provided by the track rails is not necessarily always the path of least resistance, the current may, at times, deviate from the intended track rails circuit. The deviating currents are known as leakage or stray currents and present a problem in the field of electric railway system operation and maintenance.

Stray currents may be caused by e.g. a stray can contacting a track rail, or iron dust due to wear of the railway track. Stray currents are undesirable for a variety of reasons. They may negatively affect train operation. Furthermore, they may cause deterioration or corrosion of susceptible structures in the vicinity of the tracks. For example, pipelines such as gas pipelines and other electrically conducting structures may be corroded by stray current, which may lead to failure and accidents possibly causing loss of property and life.

Based on the foregoing, it is desirable to prevent and/or to minimize stray current occurrence within electrical railway systems, and where unpreventable, it is further desirable to minimize their impact on susceptible structures. It is also necessary to continuously inspect an electric railway system for such faults as a preventive measure, and in order to ensure compliance with safety and/or legal requirements. Moreover, it would be desirable to know which areas of an electric railway track are susceptible to stray currents, so that preventive measures may be implemented.

However, due to the magnitude of the distances spanned by electric railway system tracks, it is challenging to detect presence and sources or locations of stray currents. Current methods and systems for detecting stray currents generally involve isolated, manual electrical potential measurements at different locations, which may be fixed along the tracks. This is cumbersome and impractical and generally does not provide sufficient resolution of the track. Moreover, current methods are not interchangeable for use in both AC and DC railway systems.

For example, US 6727682 B2 discloses an apparatus for remotely sensing AC current flowing in a number N of parallel conductors in a system which may be an AC railway power supply system. For each parallel conductor, two magnetic field sensors are positioned to sense a magnetic field. The sensors are enclosed within a housing and are fixedly mounted on a catenary support of an AC rail traction system, or on a pole adjacent the catenary support. Current signals, including a zero-sequence or leakage current, are derived via Fourier transformation from the measured magnetic field data.

The approach disclosed in US 6727682 B2 presents many drawbacks. Sensor instrument housings are fixedly mounted with respect to a conductor and this presents scalability issues. It is costly and impractical to install the instrument along all spans of track of a railway system. Further, the apparatus is not enabled for operation in a DC powered environment.

When taking into account the mechanical performance of the track, the track rails and supporting sleeper structure and ballast are subjected to time-varying loads of trains passing by. Although measuring trains carrying a variety of measuring devices allow to check the position and dimensions of track rails, there is no convenient way of monitoring the internal structure of the track rails.

Therefore a need exists in the art for a scalable and convenient method and system of monitoring an electric railway system, both electrically and mechanically. Further, a need exists in the art for a scalable and convenient method and system of detecting stray currents in both AC and DC powered railway systems and which provides sufficient resolution as needed.

SUMMARY OF THE INVENTION

It would be desirable to provide a method and system for monitoring an electric railway system both mechanically and electrically. It would further be desirable to provide a method and system for detecting the presence or absence of stray currents in an electric railway system. It would also be desirable to provide a method and system to detect a location or approximate location of a stray current in an electric railway system. It would further be desirable to provide such method and system which are scalable and easy to implement.

To better address one or more of these concerns, in a first aspect of the invention a method for monitoring an electric railway system track is provided, the method comprising the following steps (a) to (d). In a step (a), providing at least one magnetic field sensor configured to sense values of a magnetic field parameter. In a step (b), moving the magnetic field sensor along the track. In a step (c), sensing, by the magnetic field sensor, magnetic field parameter values at sensing locations along the track. In a step (d), processing the sensed magnetic field parameter values to determine a condition of the track.

In the method according to the invention, at least one magnetic field sensor is used for sensing values of a magnetic field parameter. A magnetic field parameter may e.g. be the magnetic flux density B, expressed in tesla (T).

A magnetic field parameter may be sensed in a particular direction, such as one of mutually orthogonal X, Y and Z directions defined in space. An X direction may be defined parallel to a longitudinal direction of a track rail of the electric railway system, and then may have a generally horizontal direction. A Y direction may be defined at right angles to a longitudinal direction of a track rail of the electric railway system, and then may have a generally horizontal direction. Accordingly, the X en Y directions may generally extend in a horizontal plane, in particular when the track rails are situated on a horizontal surface. A Z direction may be defined at right angles to both the X direction and the Y direction, and then may have a generally vertical direction.

Different magnetic field sensors may be provided for different directions, e.g. a magnetic field sensor for each one of the X, Y and Z directions.

Each magnetic field sensor is moved or displaced along the railway track. The displacement or movement may occur along the track itself, or adjacent to it, or above it. The movement or displacement may occur along a track rail, in particular parallel to the track rail, more in particular near or in the vicinity of, or adjacent to the track rail.

During the movement or displacement, magnetic field values are sensed by the magnetic field sensor(s). More specifically, the magnetic field parameter may be sensed centrally or decentrally above, or in the vicinity of, a rail of the railway track, sensing in particular an X component (i.e., a component in the X direction), a Y component (i.e., a component in the Y direction), and/or Z component (i.e. a component in the Z direction) of the magnetic field. The sensed magnetic field parameter values may be stored, or temporarily stored, and/or processed immediately, or processed at a later stage.

When no current flows in the rails of the railway track, the magnetic field sensors sense an intrinsic magnetic field profile of the rails. This profile may be analyzed to recognize patterns which are characteristic of specific problems of the track.

When a current flows in the rails of the railway track, the magnetic field sensors sense both an intrinsic magnetic field profile of the rails, and a magnetic field generated by the current. When stray current occurs at a sensing location, or at sensing locations, this can be recognized in the sensed magnetic field parameter values, since the current in the rail changes at such sensing locations.

In an embodiment of the method, step (b) comprises: mounting the magnetic field sensor on a vehicle configured for displacement along the track; and moving the vehicle along the track.

A movement or displacement of the one or more magnetic field sensors mounted on a vehicle which is configured for displacement along the track ensures that the sensor will have a known position relative to the railway track, in particular a known position relative to a rail or the rails of the railway track. With such known position, magnetic field parameter values sensed by the magnetic field sensor(s) from one location along the track to other locations can be measured, wherein different magnetic field parameter values sensed at different locations are representative of different magnetic circumstances at such different locations, and wherein such different magnetic field parameter values are essentially not attributable to variations in the position of the magnetic field sensor(s) relative to the railway track.

The vehicle may be without any motor to displace it, in which case it can be displaced by hand. Alternatively, the vehicle may have a motor for displacement, such as an internal combustion engine or an electric engine. In case of an electric engine, power may be supplied by batteries or from a railway track overhead line or railway track third (power) rail. The vehicle may be a rail-guided vehicle, in particular a rail-guided vehicle adapted to move on and/or be guided along or by the railway track. The vehicle may be a train or a tram or a part thereof.

As an example, the step of processing the sensed magnetic field parameter values in accordance with the invention may comprise storing the sensed magnetic field parameter values. Alternatively, or additionally, the step of processing the sensed magnetic field parameter values may comprise analyzing the sensed magnetic field parameter values.

The determination of a condition of the railway track may involve a human or machine evaluation of the sensed magnetic field parameter values. The condition may be expressed as a parameter, such as a number from x to y, where one of the number x and the number y indicates a good condition, and the other one of the number x and the number y indicates a bad condition, and numbers between x and y indicate an intermediate condition. The condition may also be expressed in different colors or different sounds, depending on the actual condition. The condition may be expressed locally along the railway track, or for one or more predetermined sections of the railway track, or for the whole railway track.

With the method of the invention, making measurements of magnetic field parameter values at a series of sensing locations, a magnetic “signature” (which may also be called “profile”) of the track may be obtained, where such signature in fact is a function of magnetic field parameter values plotted against sensing locations. This signature may indicate a normal or expected condition of the railway track, or may indicate an abnormal condition, in particular showing abnormal magnetic field parameter values at one or more sections of the railway track. In particular, a location of a stray current may be determined.

In an embodiment, the method further comprises steps (e) and (f). In a step (e), generating sensing location data corresponding to sensing locations along the track. In a step (f), correlating sensed magnetic field parameter values to the sensing location data.

In the monitoring of an electric railway system track according to the present disclosure, magnetic field parameter values may be obtained at virtually all locations along the railway track. When determining a condition of the track, locations of interest are to be found which require attention, inspection, and possible maintenance or repair. In order to perform such work, the sensing of magnetic field parameter values is accompanied by generating sensing location data, and the sensed magnetic field parameter values are correlated to corresponding sensing location data to be able to find an actual, physical location along the railway track where an analysis of the magnetic field parameter values has shown to be a location of interest.

In general, the sensing location data can be determined in various ways, such as by detecting an absolute sensing location having associated absolute sensing location data, or by detecting a relative sensing location wherein the sensing location is determined relative to another location which may be referred to as a reference location. The reference location in itself may be an absolute location or a relative location. An absolute sensing location may have location coordinates in two or three dimensions, which may be determined using an appropriate Global Navigation Satellite System, GNSS, such as the well-known GPS, Galileo, GLONASS, or Beidou systems. A relative sensing location may have location coordinates, each of which are relative to other (absolute or relative) location coordinates.

Advantageously, a relative sensing location may be determined along a track relative to a reference location on the track to obtain a distance along the track between the reference location and the sensing location. The distance may form straightforward sensing location data. When the route of the railway track is known, then also the sensing location is known. When the absolute reference location is known, and the distance is known (including the direction along the track in which the distance is measured), then also the absolute sensing location can be determined when the route of the railway track is known.

Thus, in an embodiment of the method, wherein the railway track comprises a reference location, step (e) comprises: determining a distance between the reference location and the sensing location; and calculating, based on the distance, the sensing location data. A reference location may comprise a predetermined magnetic inhomogeneity of the railway track, such as a welded or weldless joint between sections of a track rail, or may be a switch, or a bridge, which by the way can also be regarded as magnetic inhomogeneities.

In an embodiment of the method, the step of determining the distance between the reference location and the sensing location comprises: counting a number of revolutions of a wheel rolling along the railway track from the reference location to the sensing location, wherein the wheel has a predetermined circumference; and calculating a distance between the reference location and the sensing location by multiplying the number of revolutions by the circumference. The wheel may be a wheel of said vehicle.

In a further embodiment of the method, wherein the railway track comprises rail support structures, wherein the step of determining the distance between the reference location and the sensing location comprises: detecting a number of rail support structures from the reference location to the sensing location; and calculating a distance between the reference location and the sensing location by multiplying the number of rail support structures by a rail support structures interval or an average rail support structure interval.

It is noted that, if the rail support structure interval from one rail support structure to a next rail support structure is not constant, a pattern of rail support structures can also be matched with an earlier recorded pattern of rail support structures associated with geographical information. The sensing location data can then be determined by matching the actual, detected pattern to the recorded pattern and/or matching the actually counted number of rail support structures to the recorded pattern.

It is noted that the term ‘rail support structure’ includes any structure adapted to support a rail or the rails of a railway track at more or less regular, or predetermined intervals, such as a sleeper, a support element or a support block on a foundation, ground or bed, or another transverse connection between rails such as a bar e.g. in case of prefabricated tram rails.

In a further embodiment of the method, in which a number of rail support structures is detected to determine a relative sensing location, detecting the number of rail support structures comprises: detecting, among the sensed magnetic field parameter values, a number of series of sensed magnetic field parameter values, each series being representative of a rail support structure.

Advantageously, it has been found that in some railway track configurations the magnetic field varies at each rail support structure such that the presence of a rail support structure may be determined from a series of sensed magnetic field parameter values. Within the series, the magnetic field parameter values vary in a predetermined way, caused by e.g. the rail support structure itself or e.g. rail clamps employed to fix a track rail on the rail support structure. The variation may be detected and evaluated to represent the presence of a rail support structure. Counting the number of series of magnetic field parameter values identifiable as being associated with a rail support structure, and multiplying this number by an rail support structure interval, may provide a distance from a reference location to a sensing location.

In an embodiment, the method further comprises: performing steps (b) to (d) a first time for the track; after a predetermined time period, performing steps (b) to (d) a second time for the track; and determining, for each sensing location, a difference value between the sensed magnetic field parameter value obtained the first time and the sensed magnetic field parameter value obtained the second time to provide a series of difference values; and processing the difference values to determine a condition of the track.

As explained above, by moving a magnetic field sensor along the railway track, and sensing magnetic field parameter values at sensing locations along the track, and processing the sensed magnetic field values, a signature of the railway track as a series of magnetic field parameter values may be obtained. When the process of sensing magnetic field parameter values is repeated after a predetermined time period, which may be e.g. a day, a number of days, a week, a number of weeks, a month, a number of months, a year, a number of years, etc., then a plurality of signatures is obtained, and local changes of magnetic field parameter values (difference values) in time at the same sensing locations can be established. Taking into account that each railway track will have a unique signature in the context of one measurement along the railway track, it is the repetition of the measurement after a predetermined time period that may highlight local changes of sensed magnetic field parameter values, as indicated by the difference values. The higher the difference values, the more pronounced the changes are. Clearly identifiable changes indicate sensing locations to which particular attention should be paid, since such sensing locations may need maintenance and/or repair in particular.

In an embodiment, the method further comprises: feeding a current into at least one track rail at a current inflow point for the current to flow from the current inflow point along a current path to a current outflow point of the at least one track rail. Alternatively, the method further comprises: applying a voltage between at least one track rail and earth at a voltage application point, so that current may flow from the voltage application point, being a current inflow point, along a current path to a current outflow point of the at least one track rail.

The advantage of a current flowing in the at least one track rail is that the magnetic field parameter values which can be measured by the magnetic field sensor moving along the track may be considerably higher than the magnetic field parameter values which can be measured in the absence of a current flowing through the rail, since the current generates an electromagnetic field proportional to the value of the current.

In a further embodiment, the method further comprises a step (g) of comparing, for a portion of the current path comprising a first sensing location and a second sensing location different from the first sensing location, a first sensed magnetic field parameter value at the first sensing location with a second sensed magnetic field parameter value at the second sensing location, and if first sensed magnetic field parameter value differs from the second sensed magnetic field parameter value by a predetermined amount, then marking the portion of the current path as a stray current portion. In a particular embodiment of the method, the first sensing location is closer to the current inflow point than the second sensing location, and if first sensed magnetic field parameter value is higher than the second sensed magnetic field parameter value by a predetermined amount, then marking the portion of the current path as a stray current portion.

According to these embodiments, advantageously locations of stray current can be recognized in that a more or less stepwise change of the magnetic field parameter values sensed along the rail occurs at the stray current location. The current may be a DC current, or an AC current having a predetermined frequency.

In a further embodiment, the method further comprises: providing, for the magnetic field sensor, a proportionality factor between a sensed magnetic field parameter value and a value of a current flowing in the at least one track rail; calculating a difference between the first sensed magnetic field parameter value and the second sensed magnetic field parameter value; and calculating a value of the stray current by multiplying said difference by said proportionality factor.

Advantageously, in some instances, with a known magnitude of the current at the current inflow point, and the corresponding magnetic field parameter value(s), it may even be possible to determine the magnitude of the stray current from the change of the magnetic field parameter values at the stray current location, by applying a known relationship (factor) between the magnitude of the current in the rail and the corresponding magnetic field parameter.

Advantageously, in an embodiment of the method, the magnetic field sensor is configured to sense an X, Y and/or Z component of the magnetic field parameter, wherein the X direction is a direction parallel to a longitudinal direction of a track rail, substantially horizontally, wherein the Y direction is a direction at right angles to a longitudinal direction of a track rail, substantially horizontally, in particular a direction in a plane connecting the top sides of the rails of a railway track, and wherein the Z direction is a direction at right angles to both the X direction and the Y direction, substantially vertically, in particular a direction at right angles to a plane connecting the top sides of the rails of a railway track.

In practice, it has been generally found that sensing a Z and/or Y component of a magnetic field parameter may reliably provide magnetic field parameter values for use in the method of the invention. Also, it has been found that adjacent to the head of the track rail an X component of a magnetic field parameter shows a higher gradient at a point-like change of the stray current than the Y component or Z component.

In an embodiment, the method comprises positioning the magnetic field sensor centrally above a track rail, whereby disturbing magnetic influences of parts of the rail, such as the base part, or disturbing influences of rail mounting components, such as clamps or bolts made from a magnetizable material, are suppressed as much as possible.

In a second aspect of the invention, a system for monitoring a railway track of an electric railway system is provided, the system comprising: a vehicle configured for displacement along the track; at least one magnetic field sensor arranged on the vehicle, the magnetic field sensor configured to sense values of a magnetic field parameter; and a control and processing device for controlling the magnetic field sensor to sense magnetic field parameter values at sensing locations along the track, and processing the sensed magnetic field parameter values to determine a condition of the track.

The system implements the method of the invention. With the system of the invention, wherein at least one magnetic field sensor can make measurements of magnetic field parameter values at a series of sensing locations, a magnetic “signature” of the track may be obtained, where such signature in fact is a function of magnetic field parameter values plotted against sensing locations. This signature may indicate a normal or expected condition of the railway track, or may indicate an abnormal condition, in particular showing abnormal magnetic field parameter values at one or more sections of the railway track. In particular, a location of a stray current may be determined.

In an embodiment of the system, the vehicle comprises wheels movable on rails of the track.

A movement or displacement of the one or more magnetic field sensors mounted on a vehicle which is configured for displacement along the track ensures that each magnetic field sensor will have a known position relative to the railway track, in particular a known position relative to a rail or the rails of the railway track. With such known position, magnetic field parameter values sensed by the magnetic field sensor(s) from one location along the track to other locations can be measured, wherein different magnetic field parameter values sensed at different locations are representative of different magnetic circumstances at such different locations, and wherein such different magnetic field parameter values are essentially not attributable to variations in the position of the magnetic field sensor(s) relative to the railway track.

The control and processing device may be in the immediate periphery of the sensor, inside or outside the vehicle, or it may be at least partly remote. The control and processing device may be configured to provide the at least one magnetic field sensor with instructions, such as operation, activation/deactivation and data sampling instructions.

In an embodiment of the system, the at least one magnetic field sensor is arranged above a rail of the track, in particular centrally above a rail of the track.

Such arrangement advantageously suppresses disturbing magnetic influences of parts of the rail, such as the base part, or disturbing influences of rail mounting components, such as clamps or bolts made from a magnetizable material, to a considerable extent, although also other arrangements may be useful, in particular having the at least one magnetic field sensor decentrally above a track rail.

In an embodiment of the system, the control and processing device further is configured for: generating sensing location data corresponding to sensing locations along the track; and correlating sensed magnetic field parameter values to the sensing location data, as explained above. In a particular embodiment, wherein the railway track comprises a reference location, the control and processing device further is configured for: determining a distance between the reference location and the sensing location; and calculating, based on the distance, the sensing location data.

In an embodiment of the system, the reference location comprises a magnetic inhomogeneity.

In an embodiment of the system, the control and processing device, for determining the distance between the reference location and the sensing location, further is configured for: counting a number of revolutions of a wheel rolling along the railway track from the reference location to the sensing location, wherein the wheel has a predetermined circumference; and calculating a distance between the reference location and the sensing location by multiplying the number of revolutions by the circumference.

In another particular embodiment, the railway track comprises rail support structures, and the control and processing device further is configured for: detecting a number of rail support structures from the reference location to the sensing location; and calculating a distance between the reference location and the sensing location by multiplying the number of rail support structures by a rail support structure interterval, as explained above. In a particular embodiment, the control and processing device further is configured for: detecting, among the sensed magnetic field parameter values, a number of series of sensed magnetic field parameter values, each series being representative of a rail support structure, as explained above.

In an embodiment, the system further comprises: a current source for feeding a current into at least one track rail at a current inflow point for the current to flow from the current inflow point along a current path to a current outflow point of the at least one track rail. In such embodiment, the control and processing device further is configured for: comparing, for a portion of the current path comprising a first sensing location and a second sensing location different from the first sensing location, a first sensed magnetic field parameter value at the first sensing location with a second sensed magnetic field parameter value at the second sensing location, and if first sensed magnetic field parameter value differs from the second sensed magnetic field parameter value by a predetermined amount, then marking the portion of the current path as a stray current portion.

In an alternative embodiment, the system further comprises: a voltage source for applying a voltage between at least one track rail and earth at a voltage application point, so that current may flow from the voltage application point, being a current inflow point, along a current path to a current outflow point of the at least one track rail; wherein the control and processing device further is configured for: comparing, for a portion of the current path comprising a first sensing location and a second sensing location different from the first sensing location, a first sensed magnetic field parameter value at the first sensing location with a second sensed magnetic field parameter value at the second sensing location, and if first sensed magnetic field parameter value differs from the second sensed magnetic field parameter value by a predetermined amount, then marking the portion of the current path as a stray current portion.

For marking the portion of the current path, including the first sensing location and the second sensing location, as a stray current portion, e.g. location data of the portion of the current path may be stored in a memory. The predetermined amount of difference between the first magnetic field parameter value and the second magnetic field parameter value may for example depend on an empirically determined threshold, and/or on the value of the current fed into the at least one track rail.

In an embodiment of the system, wherein the first sensing location is closer to the current inflow point than the second sensing location, the control and processing device may further be configured for marking the portion of the current path as a stray current portion, if the first sensed magnetic field parameter value is higher than the second sensed magnetic field parameter value by a predetermined amount.

Advantageously, when the relative positions of the first sensing location and the second sensing location along the at least one track rail are known, then leaking away of stray current can be positively determined when the first sensed magnetic field parameter value is higher than the second sensed magnetic field parameter value.

In an advantageous embodiment, a value of the stray current can be determined when the control and processing device further is configured for: calculating a difference between the first sensed magnetic field parameter value and the second sensed magnetic field parameter value; and calculating a value of the stray current by multiplying said difference by a proportionality factor between a sensed magnetic field parameter value and a value of a current flowing in the at least one track rail.

In some embodiments, the system further comprises a memory device controlled by the control and processing device, the memory device configured for storing sensed magnetic field parameter values.

Although it is feasible, in some embodiments of the system, for the control and processing device to output data for real-time display or input to e.g. a signaling device to signal a condition of the railway track by image, other optical signaling, or acoustical signaling, in other embodiments data can be stored in a memory for later analysis and evaluation. Such data may include sensed magnetic field parameter values, preferably in combination with sensing location data, wherein the magnetic field parameter values are mapped to the sensing location data.

In some embodiments of the system, at least one of the memory device and at least part of the control and processing device is remotely located with respect to the at least one magnetic field sensor.

An advantage of remotely locating the memory device and/or at least part of the control and processing device with respect to the at least one magnetic field sensor is that, at the vehicle having the magnetic field sensor arranged on it, the magnetic field parameter values need not be stored and/or processed, which simplifies the vehicle and makes it less vulnerable to disturbances in its normal operation, taking into account the relatively rough environment in which the vehicle is to operate under sometimes severe weather conditions. At the remote location, conditions for storing and processing the magnetic field parameter values may be optimal. The remote location may e.g. be a railway monitoring station, a testing facility or a monitoring location of a supervisory body.

In an embodiment, the system further comprises a transmitter for transmitting data to the at least one of the memory device and at least part of the control and processing device, in particular when these are located at a remote location. The transmitter may be part of a communication system such as a telecommunication system operating in a public or private network. In this way, magnetic field parameter values, sensing location data and other relevant data may be transferred, e.g. by Internet, to a remote location anywhere in the world.

In a third aspect of the invention, a computer program is provided comprising computer instructions for causing, when loaded in a control and processing device of the system, the control and processing device to perform a controlling, processing, generating, correlating, detecting, calculating, comparing and marking step as explained above.

These and other aspects of the invention will be more readily appreciated as the same becomes better understood by reference to the following detailed description and considered in connection with the accompanying drawings in which like reference symbols designate like parts.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically depicts a practical situation in a railway track in which a stray current phenomenon occurs.

Figure 2 schematically depicts components of an embodiment of a railway track monitoring system of the present invention.

Figure 3 depicts a diagram of magnetic field parameter values in a simulated environment of stray currents in a railway track rail at different stray current values.

DETAILED DESCRIPTION OF EMBODIMENTS

Figure 1 depicts a railway track 2 comprising rails on which a train 4 may move. An overhead line 6 which may be mechanically and electrically contacted by a pantograph of the train 4, is supplied with electric power from a substation 8 providing AC or DC electric power. As indicated by arrow 10, an electric current may flow from the substation 8 through the overhead line 6 to the train 4 and, as indicated by arrow 12, the current returns from the train 4 through the rails of the railway track 2 to the substation 8.

It is noted that instead of an overhead line 6, a third rail near the railway track 2 may provide electric power for a train, which for this purpose is provided with electric power collection shoes contacting the third rail.

The above current paths apply when the railway track 2 is electrically isolated from the ground. However, in practice this may not be the case, e.g. due to electrically conducting objects contacting the rails and the ground, or due to iron dust generated by wear of the rails and forming conducting paths between rails and ground.

Then, the return current flowing from the train 4 will partly flow through the rails of the railway track 2, as indicated by arrow 12, and will partly flow through the ground, as indicated by arrows 14, 16 and 18. The part of the current straying from the intended path is indicated as stray current. As indicated in Figure 1 by arrow 16, the stray current may take a path through an electrically conducting object, such as a pipeline 20 to flow from the train 4 to the substation 8. In particular, stray current flows from railway track 2 through the ground, as indicated by arrow 14, to the pipeline 20, next through the pipeline 20, as indicated by arrow 16, and next through the ground, as indicated by arrow 18. It is to be noted that in practice the paths of the current in the ground may be more diffuse depending on local ground conditions. It is further noted that the (magnitude and paths of) stray currents at least vary not only with the current supplied to the train 4, but also with the location of the train 4 on the railway track 2.

Stray currents can induce and accelerate electrolytic corrosion of metallic structures buried in the vicinity of a railway track, which is highly undesirable. Here, direct currents have a higher effect than alternating current, since in case of alternating current the anode-cathode reactions occurring at a positive half cycle of the stray current are partially reversed in the negative half cycle of the stray current.

Figure 2 illustrates components of an embodiment of a railway track monitoring system of the present invention. A vehicle 22 movable on wheels 24 along a railway track comprising rails 26, 28 carries at least one magnetic field sensor 30. The at least one magnetic field sensor is arranged on the vehicle 22 to be above the rail 26, in particular, but not necessarily, centrally above the rail 26.

The at least one magnetic field sensor may be any type of sensor suitable for sensing a magnetic field parameter value such as, but not limited to, a Hall effect sensor, magneto-diode, a magneto-transistor, an AMR magnetometer, a GMR magnetometer, a magnetic tunnel junction magnetometer, magneto-optical sensor, a Lorentz force-based MEMS sensor, an Electron Tunneling-based MEMS sensor, a MEMS compass, a nuclear precession magnetic field sensor, an optically-pumped magnetic field sensor, a fluxgate magnetometer, a search coil magnetic field sensor, or a SQUID magnetometer. In an embodiment comprising a plurality of magnetic field sensors, a single type of sensor, or a combination of several of the aforementioned types of sensors, may be employed.

A control and processing device 32 is coupled (where this coupling is indicated by line 34) to the magnetic field sensor 30, and is arranged to control the magnetic field sensor 30 to sense magnetic field parameter values at sensing locations along the rail 26. As indicated by dashed lines, a further magnetic field sensor 36 may be carried by the vehicle 22 to sense magnetic field parameter values at sensing locations along the rail 28, and the further magnetic field sensor 36 may be coupled to the control and processing device 32, as indicated by dashed line 38. The arrangement of the further magnetic field sensor 36 with respect to the rail 28 may be similar to the arrangement of the magnetic field sensor 30 with respect to the rail 26.

In view of a use of magnetic field sensors 30 and 36, it is noted that current may pass from rail 26 to rail 28 and vice versa, e.g. as a result of a deliberately provided current path such as a rail transformer, or through an axle that supports wheels 24. Using two magnetic field sensors 30, 36, one for each rail 26, 28, respectively, allows to differentiate between stray current actually flowing away from a rail, and current just crossing, via said current path, from one rail to the other.

A memory device 40 may be coupled to the control and processing device 32 for the control and processing device 32 to store magnetic field parameter values sensed along the rails 26, 28. A location sensing device 42 may be coupled to the control and processing device 32, for generating sensing location data corresponding to sensing locations along the railway track, in particular along the rails 26, 28. The control and processing device 32 may be configured to link or correlate a magnetic field parameter value sensed at a particular sensing location to the sensing location data generated for the particular sensing location, and may further be configured to store a magnetic field parameter value and the sensing location data linked or correlated thereto in the memory device 40 for later retrieval.

In an embodiment, the location sensing device 42 comprises a receiver for a Global Navigation Satellite System, GNSS, which receiver is configured to provide location data, such as location coordinates.

In another embodiment, no dedicated location sensing device 42 is provided, but in fact the control and processing device 32 is configured for generating sensing location data corresponding to sensing locations along the track by determining a distance between a reference location and the sensing location, and calculating, based on the distance, the sensing location data.

In a further embodiment, the control and processing device 32 is configured for generating sensing location data corresponding to sensing locations along the track by determining a number of revolutions of a wheel moving along the track from the reference location to the sensing location, wherein the wheel has a predetermined circumference, and calculating a distance between the reference location and the sensing location by multiplying the number of revolutions by the circumference.

In another embodiment, the control and processing device 32 is configured for generating sensing location data corresponding to sensing locations along the track by detecting a number of rail support structures, e.g. sleepers, from a reference location to a sensing location, next calculating a distance between the reference location and the sensing location by multiplying the number of sleepers by an average sleeper-to-sleeper distance, and next calculating, based on this distance, the sensing location data. Sleepers can be detected by recognizing characterizing patterns in sensed magnetic field parameter values. For this purpose, advantageously the control and processing device is configured for detecting, among a plurality of sensed magnetic field parameter values, a number of series of sensed magnetic field parameter values each representative of a sleeper. Alternatively, sleepers can be detected by optical detection, using a camera and image processing software.

A display device 44 may be coupled to the control and processing device 32 for displaying information representative of sensed magnetic field parameter values, and/or a condition of the railway track derived from the sensed magnetic field parameter values. For example, the display device 44 may show a graph of sensed magnetic field parameter values plotted against sensing locations. Such graph may be visually inspected by an inspector, or may be automatically analyzed by appropriate software to detect predefined conditions.

One or more of the control and processing device 32, the memory device 40, the location sensing device 42 and the display device 44 may be part of one computing device, such as a portable computer, tablet computer, smartphone, etc.. The control and processing device 32, the memory device 40, the location sensing device 42 and the display device 44 may be mounted on the vehicle 22.

In an embodiment, the magnetic field sensor 30, 36 may be moved along a railway track a first time to thereby sense magnetic field parameter values at sensing locations along the track, and thereafter the magnetic field sensor 30, 36 may be moved a further time along the same railway track to thereby again sense magnetic field parameter values at the same sensing locations, where averaging of sensed magnetic field parameter values may be performed if the sensing locations of the first time and the second time do not coincide. Then, for each sensing location, a difference value between the sensed magnetic field parameter value obtained the first time and the sensed magnetic field parameter value obtained the second time may be determined, to provide a series of difference values. With a relevant time period, e.g. in the order of a day, in the order of a week, in the order of a month, in the order of a quarter year, in the order of half a year, or in the order of a year between the first time and the second time, the difference values provide useful information on the development of the condition of the railway track, in particular at sensing locations showing (absolute) difference values above a predetermined threshold value.

Although the sensing of magnetic field parameter values provides important information about a condition of the railway track when no current flows in the (rails of the) track, so that the method and system of the invention are very useful under such circumstances, the method and system are particularly useful when a current is fed into at least one track rail 26, 28 by a current source 90 at a current inflow point 92 for the current to flow from the current inflow point along a current path to a current outflow point of the at least one track rail 26, 28, where the sensing locations are between the current inflow point and the current outflow point. Alternatively, the current in the track rail 26, 28 may be caused to flow by a voltage source 94 applying a voltage between at least one track rail 26, 28 and earth, at a voltage application point 96. The current in the track rail generates a magnetic field in the vicinity of the track rail. This magnetic field generated by the current is proportional to the current. For a predefined magnetic field measuring configuration of a magnetic field sensor and a track rail, a proportionality factor can be established between a magnetic field parameter value sensed by the magnetic field sensor, and a value of the current flowing in the track rail. In practice, however, the track rail has an intrinsic magnetization which is present with or without a current flowing through the track rail. The intrinsic magnetization provides local biases in the magnetic field parameter value measurement of magnetic fields generated by a current flowing in a rail. A higher current decreases the relative disturbance of the intrinsic magnetization on the measurement of the current flowing in the track rail through measurement of the magnetic field parameter value.

Figure 3 shows, as an example, a series of graphs of magnetic field parameter values sensed at different sensing locations of a track rail, wherein each graph represents magnetic field parameter values for a particular value of a DC current flowing in the track rail. The magnetic field sensor has substantially the same relative position with respect to the track rail in the different sensing locations.

In Figure 3, on the horizontal axis indications of sensing locations are given in units of distance running from 0 to 40. On the vertical axis, magnetic field parameter values are given, in units running from +2000 to -18000.

Six graphs 71, 72, 73, 74, 75 and 76 are depicted, in particular magnetic field parameter values for different sensing locations, when currents in the track rail are 0 A, 20 A, 30 A, 40 A, 50 A and 60 A, respectively.

From the graphs 71 to 76, it can be seen that there is a considerable intrinsic magnetization. For sensing locations between 0 and 10, a gradually decreasing negative intrinsic magnetization can be recognized. For sensing locations between 10 and 17, a positive bump in the intrinsic magnetization can be recognized. For sensing locations above 17, a gradually decreasing negative intrinsic magnetization can be recognized.

From the sensing location 10, and at a current of 60 A, a proportionality factor of about -16700/60 = -278/A for the magnetic field parameter value can be determined.

Based on this notion, when a current is caused to flow in a track rail, and at some measuring point along the track rail between the current inflow point and the current outflow point a drop in magnetic field parameter value is sensed, then it may be concluded that at said measuring point a stray current originates. It may also be concluded, taking into account a proportionality factor, what magnitude the stray current has (or what proportion of the injected track rail current leaks away as stray current at the measuring point).

The determination of a stray current comprises, while feeding a current into at least one track rail at a current inflow point for the current to flow along a current path to a current outflow point of the at least one track rail, the steps of comparing, for a portion of the current path comprising a first sensing location and a second sensing location different from the first sensing location, a first sensed magnetic field parameter value at the first sensing location with a second sensed magnetic field parameter value at the second sensing location, and if first sensed magnetic field parameter value differs from the second sensed magnetic field parameter value by a predetermined amount, then marking the portion of the current path as a stray current portion. When the first sensing location is closer to the current inflow point than the second sensing location, and if first sensed magnetic field parameter value is higher than the second sensed magnetic field parameter value by a predetermined amount, then the portion of the current path is marked as a stray current portion.

A calculation of the value of the stray current may be performed by providing, for the magnetic field sensor, a proportionality factor between a sensed magnetic field parameter value and a value of a current flowing in the at least one track rail, calculating a difference between the first sensed magnetic field parameter value and the second sensed magnetic field parameter value, and calculating a value of the stray current by multiplying said difference by said proportionality factor.

In Figure 3, five further graphs 82, 83, 84, 85 and 86 are depicted, in particular magnetic field parameter values for different sensing locations, when currents in the track rail at a current inflow point are 20 A, 30 A, 40 A, 50 A and 60 A, respectively, and when at the same time a stray current leak is occurring in (part of) a region from sensing location 10 to sensing location 30. From the graphs 82, 83, 84, 85 and 86 it appears that a clearly recognizable stray current occurs in the region from sensing location 10 to sensing location 30, as a result of which the current supplied at the current inflow point (of which the resulting magnetic field parameter values are depicted in the region of sensing locations 0-10) has decreased in absolute value in the region from sensing location 30 to 40 (as represented in the magnetic field parameter values resulting from the decreased current). Since the current decrease can be measured/sensed, the present invention provides a simple and straightforward method and system to find sensing locations where stray currents occur. After finding such stray current sensing locations, appropriate measures can be taken to find the cause of the stray current, and to restore the isolation of the railway track with respect to the ground at the particular location to stop the stray current from occurring.

The stray current sensing may be improved by first determining the intrinsic magnetic profile of the railway track by sensing magnetic field parameter values along the track while no current is flowing through the track (rails). This is represented by graph 71. Next, again magnetic field parameter values along the same track are sensed while a current is injected into a rail of the track, such as represented by graphs 82, 83, 84, 85 and 86. The magnetic field parameter values sensed at zero current can then be subtracted from the magnetic field parameter values sensed while current flows in the track, whereby the contribution of the current and possible stray currents to the magnetic field parameter values can be determined more accurately.

Returning to Figure 2, as an alternative to control and processing device 32 and coupled devices 40, 42, 44, or in addition thereto, another control and processing device 52 may control the magnetic field sensors 30, 36 to generate magnetic field parameter values sensed at sensing locations along the rail 26. A location sensing device similar to the location sensing device 42 may be coupled to the control and processing device 52.

A transmitter 54 is coupled to the other control and processing device 52, and is configured to transmit magnetic field parameter value data, possibly supplemented with corresponding sensing location data, to a network 56. The network 56 may be any suitable (tele)communication network, in particular a wireless data communication network. The other control and processing device 52 and the transmitter 54 may be mounted on the vehicle 22.

A receiver 58 is coupled to the network 56, and is configured to receive the magnetic field parameter value data transmitted by the transmitter 54 at a remote location. The receiver is coupled to a further control and processing device 60, which in turn may be coupled to a memory device 62 for storing and retrieving magnetic field parameter values by the further control and processing device 60 and a display device 64.

Functions performed by the control and processing device 32, the other control and processing device 52, and the further control and processing device 60 may be similar, or may complement each other depending on e.g. system requirements, reliability considerations, data transmission considerations and costs.

A vehicle 22 may be moved by hand, or have a propulsion device. The vehicle may be an AC powered or DC powered train such as a passenger train or a freight train. The vehicle may be a vehicle intended exclusively for stray current detection operations. Alternatively, the vehicle may be a maintenance vehicle for use in track maintenance operations. The vehicle may be configured or adaptable for displacement along both track rails and roads. At least one magnetic field sensor is arranged on the vehicle, either inside the body of the vehicle or outside the body of the vehicle, and is configured to execute a sensing operation as the vehicle is displaced along, alongside and/or above a track of the electric railway system.

In a further embodiment, at least two magnetic field sensors are spatially arranged along an axis substantially parallel to a longitudinal central axis of at least one rail of the track. In such embodiment, each magnetic field sensor may be configured to function substantially independently of the other sensor or sensors. This arrangement provides for verification and comparison of sensed data corresponding to identical sensing locations or sensing times.

As explained in detail above, in a system and method for monitoring an electric railway system track, at least one magnetic field sensor is provided, which is configured to sense values of a magnetic field parameter. The magnetic field sensor is moved along the track, and senses magnetic field parameter values at sensing locations along the track. The sensed magnetic field parameter values are processed to determine a condition of the track. The magnetic field sensor is mounted on a vehicle configured for displacement along the track. The vehicle is moved along the track.

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting, but rather, to provide an understandable description of the invention.

The term "a"/"an", as used herein, is defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language, not excluding other elements or steps). Any reference signs in the claims should not be construed as limiting the scope of the claims or the invention.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The term coupled, as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically. In case of electronic devices, the term coupled may indicate a wired or wireless coupling.

A single processor or other processing unit of the control and processing device may fulfil the functions of several items recited in the claims.

The term computer program as used herein, is defined as a sequence of instructions designed for execution on a computer system. A computer program may include a subroutine, a function, a procedure, an object method, an object implementation, an executable application, an applet, a servlet, a source code, an object code, a shared library/dynamic load library and/or other sequence of instructions designed for execution on a computer system.

A computer program may be stored and/or distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed and/or used in other forms, such as via the Internet or other wired or wireless (tele)communication systems.

CONCLUSIES

1. Werkwijze voor het controleren van een elektrische-spoorwegsysteembaan, omvattende:

(a) verschaffen van tenminste een magnetisch-veldsensor geconfigureerd voor het meten van waarden van een magnetisch-veldparameter;

(b) bewegen van de magnetisch-veldsensor langs de baan;

(c) meten, door middel van de magnetisch-veldsensor, van magnetisch-veldparameterwaarden op meetlocaties langs de baan; en

(d) verwerken van de gemeten magnetisch veldparameterwaarden voor het bepalen van een staat van de baan.

2. Werkwijze volgens conclusie 1, waarbij stap (b) omvat:

monteren van de magnetisch-veldsensor op een voertuig dat is geconfigureerd om te worden verplaatst langs de baan; en

bewegen van het voertuig langs de baan.

3. Werkwijze volgens conclusie 1, verder omvattende:

(e) genereren van meetlocatiedata die corresponderen met meetlocaties langs de baan; en

(f) correleren van gemeten magnetisch-veldparameterwaarden met de meetlocatiedata.

4. Werkwijze volgens conclusie 3, waarbij de spoorwegbaan een referentielocatie omvat, en waarbij stap (e) omvat:

bepalen van een afstand tussen de referentielocatie en de meetlocatie; en

berekenen, op basis van de afstand, van de meetlocatiedata.

5. Werkwijze volgens conclusie 4, waarbij de referentielocatie een magnetische inhomogeniteit omvat.

6. Werkwijze volgens conclusie 4, waarbij de stap van het bepalen van de afstand tussen de referentielocatie en de meetlocatie omvat:

tellen van een aantal omwentelingen van een wiel dat rolt langs de spoorwegbaan van de referentielocatie tot de meetlocatie, waarbij het wiel een vooraf bepaalde omtrek heeft; en

berekenen van een afstand tussen de referentielocatie en de meetlocatie door het vermenigvuldigen van het aantal omwentelingen met de omtrek.

7. Werkwijze volgens conclusie 4, waarbij de spoorwegbaan railsteunstructuren omvat, en waarbij de stap van het bepalen van de afstand tussen de referentielocatie en de meetlocatie omvat:

detecteren van een aantal railsteunstructuren van de referentielocatie tot de meetlocatie; en

berekenen van een afstand tussen de referentielocatie en de meetlocatie door het vermenigvuldigen van het aantal railsteunstructuren met een railsteunstructuurinterval.

8. Werkwijze volgens conclusie 7, waarbij het detecteren van het aantal railsteunstructuren omvat:

detecteren, onder de gemeten magnetisch-veldparameterwaarden, van een aantal reeksen gemeten magnetisch-veldparameterwaarden, waarbij elke reeks een railsteunstructuur representeert.

9. Werkwijze volgens conclusie 7 of 8, waarbij de railsteunstructuur een dwarsligger is.

10. Werkwijze volgens een of meer van de voorgaande conclusies, verder omvattende:

een eerste maal uitvoeren van stappen (b) tot en met (d) voor de baan;

na een vooraf bepaalde tijdsperiode, een tweede maal uitvoeren van stappen (b) tot en met (d) voor de baan; en

bepalen, voor elke meetlocatie, van een verschilwaarde tussen de eerste maal verkregen gemeten magnetisch-veldparameterwaarde en de tweede maal verkregen gemeten magnetisch-veldparameterwaarde voor het verschaffen van een reeks verschilwaarden; en

verwerken van de verschilwaarden voor het bepalen van een staat van de baan.

11. Werkwijze volgen een of meer van de conclusies 1 tot en met 10, verder omvattende:

voeden van een stroom in ten minste een baanrail op een stroominvloeipunt voor het vloeien van de stroom van het stroominvloeipunt langs een stroompad naar een stroomuitvloeipunt van de ten minste ene baanrail.

12. Werkwijze volgens een of meer van de conclusies 1 tot en met 10, verder omvattende:

aanleggen van een spanning tussen ten minste een baanrail en aarde op een spanningsaanlegpunt, zodat stroom kan vloeien van het spanningsaanlegpunt, dat een stroominvloeipunt is, langs een stroompad naar een stroomuitvloeipunt van de ten minste ene baanrail.

13. Werkwijze volgens conclusie 11 of 12, verder omvattende:

(g) vergelijken, voor een gedeelte van het stroompad omvattende een eerste meetlocatie en een tweede meetlocatie die verschilt van de eerste meetlocatie, van een eerste gemeten magnetisch-veldparameterwaarde op de eerste meetlocatie met een tweede gemeten magnetisch-veldparameterwaarde op de tweede meetlocatie, en indien de eerste gemeten magnetisch-veldparameterwaarde met een vooraf bepaalde hoeveelheid verschilt van de tweede gemeten magnetisch-veldparameterwaarde, het vervolgens markeren van het gedeelte van het stroompad als een zwerfstroomgedeelte.

14. Werkwijze volgens conclusie 13, waarbij de eerste meetlocatie dichter bij het stroominvloeipunt ligt dan de tweede meetlocatie, en indien de eerste gemeten magnetisch-veldparameterwaarde met een vooraf bepaalde hoeveelheid hoger is dan de tweede gemeten magnetisch-veldparameterwaarde, het vervolgens markeren van het gedeelte van het stroompad als een zwerfstroomgedeelte.

15. Werkwijze volgens conclusie 13 of 14, verder omvattende;

verschaffen, voor de magnetisch-veldsensor, van een proportionaliteitsfactor tussen een gemeten magnetisch-veldparameterwaarde en een waarde van een stroom die vloeit in de ten minste ene baanrail;

berekenen van een verschil tussen de eerste gemeten magnetisch-veldparameterwaarde en de tweede gemeten magnetisch-veldparameterwaarde; en

berekenen van een waarde van de zwerfstroom door het vermenigvuldigen van genoemd verschil met genoemde proportionaliteitsfactor.

16. Werkwijze volgens een of meer van de voorgaande conclusies, waarbij de magnetisch-veldsensor is geconfigureerd voor het meten van een X, Y en/of Z-component van de magnetisch-veldparameter, waarbij de X-richting een richting parallel aan een langsrichting van een baanrail is, in hoofdzaak horizontaal, waarbij de Y-richting een richting loodrecht op een langsrichting van een baanrail is, in hoofdzaak horizontaal, en waarbij de Z-richting een richting loodrecht op zowel de X-richting als de Y-richting is, in hoofdzaak verticaal.

17. Werkwijze volgens een of meer van de voorgaande conclusies, omvattende het

positioneren van de magnetisch-veldsensor boven een baanrail.

18. Werkwijze volgens een of meer van de voorgaande conclusies, waarbij de magnetisch-veldparameter de magnetische fluxdichtheid is, gemeten in tesla.

19. Systeem voor het controleren van een spoorwegbaan van een elektrisch spoorwegsysteem, waarbij het systeem omvat:

een voertuig dat is geconfigureerd voor verplaatsing langs de baan;

ten minste een magnetisch-veldsensor die is opgesteld op het voertuig, waarbij de magnetisch-veldsensor is geconfigureerd voor het meten van waarden van een magnetisch-veldparameter; en

een besturings- en verwerkingsinrichting voor het besturen van de magnetisch-veldsensor voor het meten van magnetisch-veldparameterwaarden op meetlocaties langs de baan, en het verwerken van het gemeten magnetisch-veldparameterwaarden voor het bepalen van een staat van de baan.

20. Systeem volgens conclusie 19, waarbij het voertuig wielen omvat die beweegbaar zijn op rails van de baan.

21. Systeem volgens conclusie 19 of 20, waarbij de ten minste ene magnetisch-veldsensor is opgesteld boven een rail van de baan.

22. Systeem volgens een of meer van de conclusies 19 tot en met 21, waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het genereren van meetlocatiedata die corresponderen met meetlocaties langs de baan; en

het correleren van gemeten magnetisch-veldparameterwaarden met de meetlocatiedata.

23. Systeem volgens conclusie 22, waarbij de spoorwegbaan een referentielocatie omvat, en waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het bepalen van een afstand tussen de referentielocatie en de meetlocatie; en

het op basis van de afstand berekenen van de meetlocatiedata.

24. Systeem volgens conclusie 23, waarbij de referentielocatie een magnetische inhomogeniteit omvat.

25. Systeem volgens conclusie 23, waarbij de besturings- en verwerkingsinrichting, voor het bepalen van de afstand tussen de referentielocatie en de meetlocatie, verder is geconfigureerd voor:

het tellen van een aantal omwentelingen van een wiel dat rolt langs de spoorwegbaan van de referentielocatie naar de meetlocatie, waarbij het wiel een vooraf bepaalde omtrek heeft; en

het berekenen van een afstand tussen de referentielocatie en de meetlocatie door het vermenigvuldigen van het aantal omwentelingen met de omtrek.

26. Systeem volgens conclusie 23, waarbij de spoorwegbaan railsteunstructuren omvat, en waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het detecteren van een aantal spoorsteunstructuren van de referentielocatie tot de meetlocatie; en

het berekenen van een afstand tussen de referentielocatie en de meetlocatie door het vermenigvuldigen van het aantal railsteunstructuren met een railsteunstructuurinterval.

27. Systeem volgens conclusie 26, waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het detecteren, onder de gemeten magnetisch-veldparameterwaarden, van een aantal reeksen gemeten magnetisch-veldparameterwaarden, waarbij elke reeks een railsteunstructuur representeert.

28. Systeem volgens conclusie 26 of 27, waarbij de railsteunstructuur een dwarsligger is.

29. Systeem volgens een of meer van de conclusies 19 tot en met 28, verder omvattende:

een stroombron voor het voeden van een stroom in ten minste een baanrail op een stroominvloeipunt voor het vloeien van de stroom van het stroominvloeipunt langs een stroompad naar een stroomuitvloeipunt van de ten minste ene baanrail,

waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het vergelijken, voor een gedeelte van het stroompad omvattende een eerste meetlocatie en een tweede meetlocatie die verschilt van de eerste meetlocatie, van een eerste gemeten magnetisch-veldparameterwaarde op de eerste meetlocatie met een tweede gemeten magnetisch-veldparameterwaarde op de tweede meetlocatie, en indien de eerste gemeten magnetisch-veldparameterwaarde met een vooraf bepaalde hoeveelheid verschilt van de tweede gemeten magnetisch-veldparameterwaarde, het vervolgens markeren van het gedeelte van het stroompad als een zwerfstroomgedeelte.

30. Systeem volgens een of meer van de conclusies 19 tot en met 28, verder omvattende:

een spanningsbron voor het aanleggen van een spanning tussen ten minste een baanrail en aarde op een spanningsaanlegpunt, zodat stroom kan vloeien van het spanningsaanlegpunt, dat een stroominvloeipunt is, langs een stroombaan naar een stroomuitvloeipunt van de ten minste ene baanrail,

waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het vergelijken, voor een gedeelte van het stroompad omvattende een eerste meetlocatie en een tweede meetlocatie die verschilt van de eerste meetlocatie, van een eerste gemeten magnetisch-veldparameterwaarde op de eerste meetlocatie met een tweede gemeten magnetisch-veldparameterwaarde op de tweede meetlocatie, en indien de eerste gemeten magnetisch-veldparameterwaarde met een vooraf bepaalde hoeveelheid verschilt van de tweede gemeten magnetisch-veldparameterwaarde, het vervolgens markeren van het gedeelte van het stroompad als een zwerfstroomgedeelte.

31. Systeem volgens conclusie 29 of 30, waarbij de eerste meetlocatie zich dichter bij het stroominvloeipunt bevindt dan de tweede meetlocatie, en waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

indien de eerste gemeten magnetisch-veldparameterwaarde met een vooraf bepaalde hoeveelheid hoger is dan de tweede gemeten magnetisch-veldparameterwaarde, het vervolgens markeren van het gedeelte van het stroompad als een zwerfstroomgedeelte.

32. Werkwijze volgens een of meer van de conclusies 29 tot en met 31, waarbij de besturings- en verwerkingsinrichting verder is geconfigureerd voor:

het berekenen van een verschil tussen de eerste gemeten magnetisch-veldparameterwaarde en de tweede gemeten magnetisch-veldparameterwaarde; en

het berekenen van een waarde van de zwerfstroom door het vermenigvuldigen van genoemd verschil met een proportionaliteitsfactor tussen een gemeten magnetisch-veldparameterwaarde en een waarde van een stroom die vloeit in de ten minste ene baanrail.

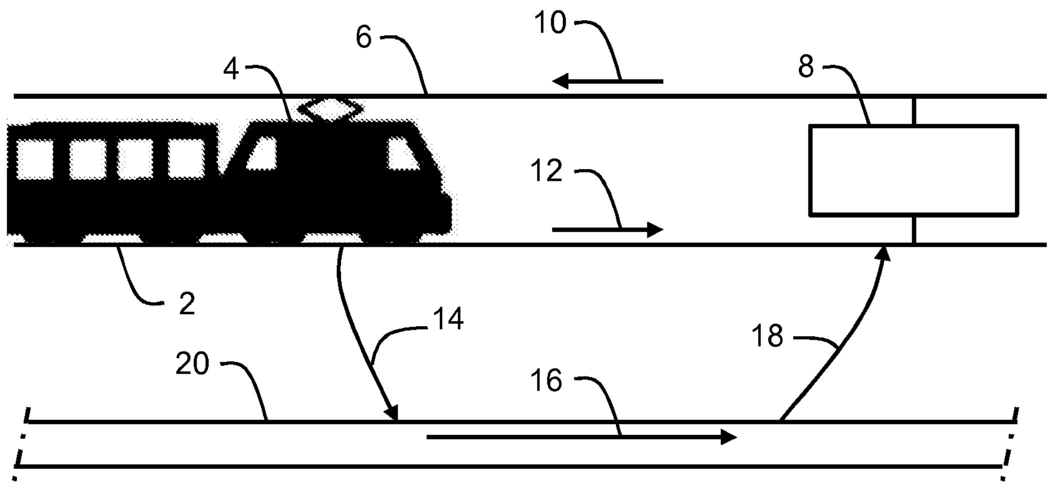
33. Systeem volgens een of meer van de conclusies 19 tot en met 32, verder omvattende een geheugeninrichting bestuurd door de besturings- en verwerkingsinrichting, waarbij de geheugeninrichting is geconfigureerd voor het opslaan van gemeten magnetisch-veldparameterwaarden.

34. Systeem volgens conclusie 33, waarbij de geheugeninrichting verder is geconfigureerd voor het opslaan van meetlocatiedata.

35. Systeem volgens conclusie 33 of 34, waarbij ten minste een van de geheugeninrichting en ten minste een deel van de besturings- en verwerkingsinrichting zich op afstand bevindt ten opzichte van de ten minste ene magnetisch-veldsensor.

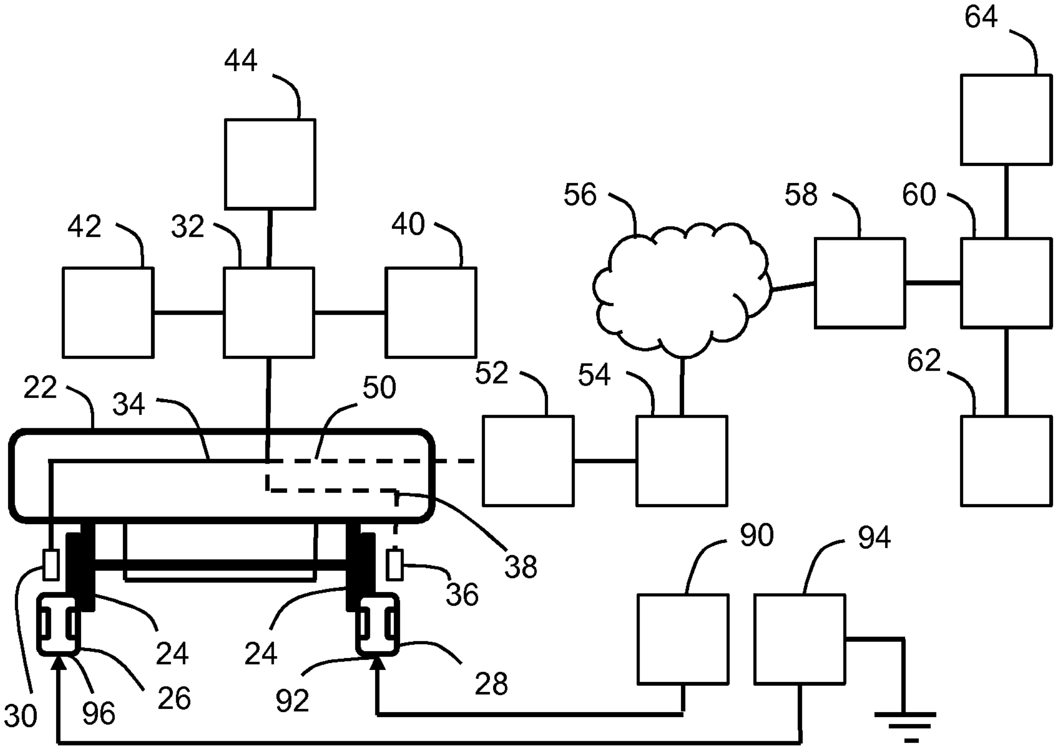
36. Systeem volgens conclusie 35, verder omvattende;
een zender voor het zenden van data naar de ten minste ene van de geheugeninrichting en ten minste een deel van de besturings- en verwerkingsinrichting.

37. Computerprogramma omvattende computerinstructies die, wanneer zij zijn geladen in een besturings- en verwerkingsinrichting, de besturings- en verwerkingsinrichting een besturen, verwerken, genereren, correleren, detecteren, berekenen, vergelijken en markeren van respectieve conclusies 19 en 22 tot en met 32 doen uitvoeren.



10
6
4
8
12
2
14
18
20
16

Fig. 1



64
44
56
58
60
42
32
40
22
34
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52
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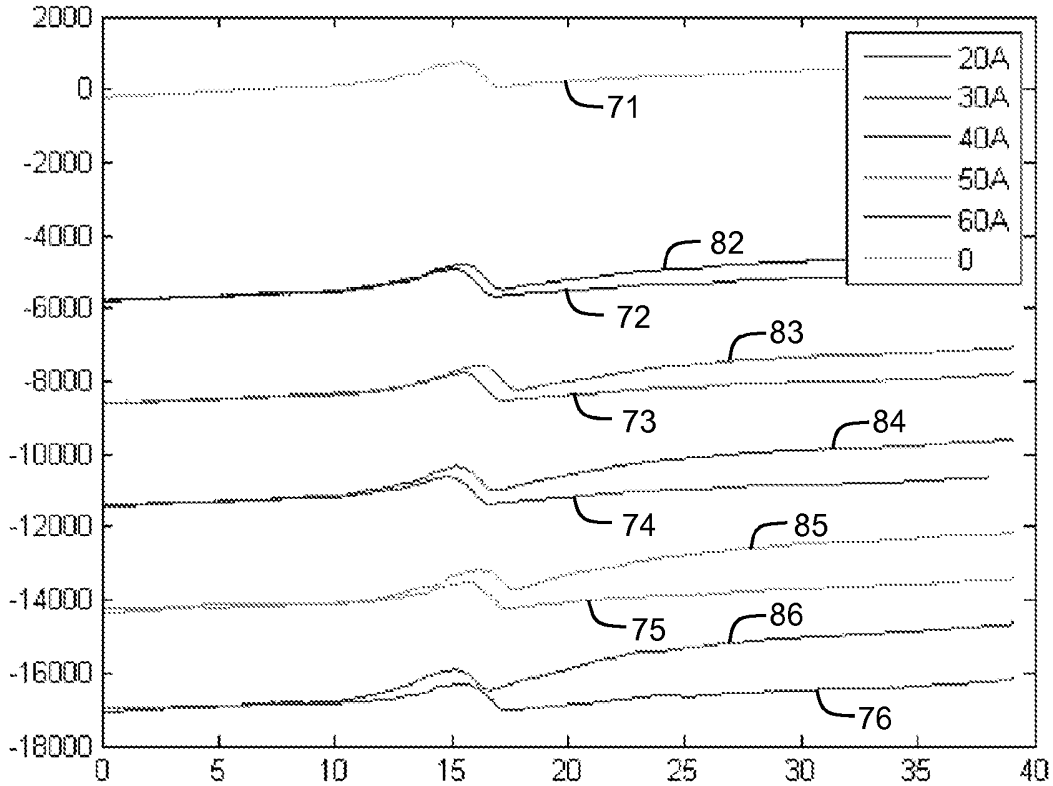
62
38
36
24
24
90
94
30
96
26
92
28

Fig. 2



2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
0
5
10
15
20
25
30
35
40
20A
30A
40A
50A
60A
0
71
82
72
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75
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Fig. 3

ABSTRACT

In a system and method for monitoring an electric railway system track, at least one magnetic field sensor is provided, which is configured to sense values of a magnetic field parameter. The magnetic field sensor is moved along the track, and senses magnetic field parameter values at sensing locations along the track. The sensed magnetic field parameter values are processed to determine a condition of the track. The magnetic field sensor is mounted on a vehicle configured for displacement along the track. The vehicle is moved along the track. A current may be fed into a track rail, or a voltage may be applied between a track rail and earth, for a current to flow through the track rail.

Fig. 2

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE **P31488NL00/ME**
Nederlands aanvraag nr. **2015770**	Indieningsdatum **11-11-2015**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Conductis B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **20-02-2016**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN65787**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

B61D15/08;B61K9/08;G01N27/83

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	**B61D;B61K;B61L,G01N**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES	(opmerkingen op aanvullingsblad)
IV.	☐	GEBREK AAN EENHEID VAN UITVINDING	(opmerkingen op aanvullingsblad)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2015770

A. CLASSIFICATIE VAN HET ONDERWERP
INV. B61D15/08 B61K9/08 G01N27/83
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte mimimum documentatie (classificatie gevolgd door classificatiesymbolen)
B61D B61K B61L G01N

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	WO 2015/120550 A1 (PURE TECHNOLOGIES LTD [CA]) 20 augustus 2015 (2015-08-20) * samenvatting * * conclusie 23 * * figuren 1,2,9A,9B,11A,11B * * alineas [0002], [0030] - [0066] * -----	1-4,10, 16-23, 33-37
X	US 2002/065629 A1 (CLARK ROBIN [US] ET AL) 30 mei 2002 (2002-05-30) * samenvatting * * figuren 9-12 * * alineas [0051], [0052], [0060], [0065], [0071] - [0080], [0102], [0116], [0123] - [0128], [0145] * ----- -/--	1,3-9, 11-15, 19, 22-32,37

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

* Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
"D" in de octrooiaanvrage vermeld
"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
"L" om andere redenen vermelde literatuur
"O" niet-schriftelijke stand van de techniek
"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

28 juli 2016

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Ruchaud, Nicolas

Formulier PCT/ISA/201 (tweede blad) (Januari 2004)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2015770

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 6 262 573 B1 (WOJNAROWSKI ROBERT JOHN [US] ET AL) 17 juli 2001 (2001-07-17) * samenvatting * * figuren 1-4 * * kolom 2, regel 40 - kolom 3, regel 58 * -----	1,18,19, 37
X	US 2005/285588 A1 (KATRAGADDA GOPICHAND [IN] ET AL) 29 december 2005 (2005-12-29) * samenvatting * * figuren 1,2,3,4 * * alineas [0002], [0017], [0018] * -----	1,19,37
X	FR 1 440 416 A (AUTOMATION IND INC) 27 mei 1966 (1966-05-27) * figuur 1 * * bladzijde 3, kolom 1 * -----	1,19
X	US 1 963 931 A (BILLSTEIN ARTHUR E F) 19 juni 1934 (1934-06-19) * figuur 1 * -----	1,19
A	EP 0 831 323 A1 (ROHRNETZBAU GMBH RBG [DE]) 25 maart 1998 (1998-03-25) * kolom 3, regels 29-40 * -----	1-37
A	WO 00/29858 A1 (SUPARULES LTD [IE]; TOBIN NOEL PATRICK [IE]) 25 mei 2000 (2000-05-25) * het gehele document * -----	1-37

5

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2015770

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)		Datum van publicatie
WO 2015120550	A1	20-08-2015	GEEN		
US 2002065629	A1	30-05-2002	AU 1306402	A	22-04-2002
			US 2002065610	A1	30-05-2002
			US 2002065629	A1	30-05-2002
			US 2002099507	A1	25-07-2002
			WO 0230729	A1	18-04-2002
US 6262573	B1	17-07-2001	GEEN		
US 2005285588	A1	29-12-2005	GEEN		
FR 1440416	A	27-05-1966	GEEN		
US 1963931	A	19-06-1934	GEEN		
EP 0831323	A1	25-03-1998	DE 19638776	A1	02-04-1998
			EP 0831323	A1	25-03-1998
WO 0029858	A1	25-05-2000	AT 232607	T	15-02-2003
			AU 771915	B2	08-04-2004
			BR 9915331	A	09-10-2001
			CA 2350535	A1	25-05-2000
			CN 1333874	A	30-01-2002
			DE 69905385	D1	20-03-2003
			DE 69905385	T2	11-12-2003
			EP 1129359	A1	05-09-2001
			JP 2002530653	A	17-09-2002
			US 6727682	B1	27-04-2004
			WO 0029858	A1	25-05-2000

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN65787	11.11.2015		NL2015770

International Patent Classification (IPC)
INV. B61D15/08 B61K9/08 G01N27/83

Applicant
Conductis B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☒ Box No. VII — Certain defects in the application
- ☒ Box No. VIII — Certain observations on the application

Examiner
Ruchaud, Nicolas

Application number

WRITTEN OPINION

NL2015770

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	6-9, 12-15, 24, 26-28, 30-32
	No:	Claims	1-5, 10, 11, 16-23, 25, 29, 33-37
Inventive step	Yes:	Claims	
	No:	Claims	1-37
Industrial applicability	Yes:	Claims	1-37
	No:	Claims	

2. Citations and explanations

   see separate sheet

WRITTEN OPINION

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 WO 2015/120550 A1 (PURE TECHNOLOGIES LTD [CA]) 20 augustus 2015 (2015-08-20)

D2 US 2002/065629 A1 (CLARK ROBIN [US] ET AL) 30 mei 2002 (2002-05-30)

D3 US 6 262 573 B1 (WOJNAROWSKI ROBERT JOHN [US] ET AL) 17 juli 2001 (2001-07-17)

D4 US 2005/285588 A1 (KATRAGADDA GOPICHAND [IN] ET AL) 29 december 2005 (2005-12-29)

D5 FR 1 440 416 A (AUTOMATION IND INC) 27 mei 1966 (1966-05-27)

D6 US 1 963 931 A (BILLSTEIN ARTHUR E F) 19 juni 1934 (1934-06-19)

D7 EP 0 831 323 A1 (ROHRNETZBAU GMBH RBG [DE]) 25 maart 1998 (1998-03-25)

D8 WO 00/29858 A1 (SUPARULES LTD [IE]; TOBIN NOEL PATRICK [IE]) 25 mei 2000 (2000-05-25)

1 **Novelty:**

1.1 Independent claim 1

1.1.1 **D1** shows een Werkwijze voor het controleren van een elektrische-spoorwegsysteembaan *(see abstract),* omvattende:

(a) verschaffen van tenminste een magnetisch-veldsensor geconfigureerd voor het meten van waarden van een magnetisch-veldparameter *(see paragraphs [0030] and [0034]; figures 1 and 2);*
(b) bewegen van de magnetisch-veldsensor langs de baan *(see paragraphs [0030] and [0034]; figures 1 and 2);*

(c) meten, door middel van de magnetisch-veldsensor, van magnetisch-veldparameterwaarden op meetlocaties langs de baan *(see paragraphs [0030] and [0034]; figures 1 and 2)*; en

(d) verwerken van de gemeten magnetisch veldparameterwaarden voor het bepalen van een staat van de baan *(see paragraph [0066]; figures 11A and 11B)*.

Claim 1 is therefore not new.

1.1.2 The patent literature provides an overflow of novelty-destroying documents in respect of the subject-matter of claim 1, see for instance:

- **D2** *(see paragraphs [0051] and [0052]; figures 9-12)*,
- **D3** *(see column 2, lines 40-65)*,
- **D4** *(see paragraphs [0002], [0017] and [0018])*,
- **D5** *(see page 3, column 1; figure 1)* and
- **D6** *(see figure 1)*.

1.2 Independent claims 19 and 37

The same reasoning applies, mutatis mutandis, to the subject-matter of the corresponding independent claims 19 and 37, which therefore are also considered not new.

1.3 Dependent claims 2-5, 10, 11, 16-18, 20-23, 25, 29 and 33-36 do not appear to contain any additional features which meet the requirements of novelty.

- claims 2 and 20: see **D1**, figure 1, reference sign 102.
- claims 3 and 22: see **D1**, paragraph [0033]; claim 23 / **D2**: paragraphs [0080] and [0126].
- claims 4 and 23: see **D1**, paragraph [0033]: "*mechanical encoders*" / **D2**: paragraphs [0126] and [0127].
- claims 5 and 25: see **D2**, paragraph [0126].
- claim 10: see **D1**, paragraph [0057].
- claims 11 and 29: see **D2**, paragraph [0072].
- claim 16: see **D1**, paragraph [0037].

- claims 17 and 21: see **D1**, figure 2A, reference signs 10 and 120.
- claim 18: see **D1**, paragraphs [0060] and [0066] / **D3**: column 3, lines 7-8.
- claims 33-36: see **D1**, paragraph [0030].

2 **Inventive step:**

Dependent claims 6-9, 12-15, 24, 26-28 and 30-32 do not appear to contain any additional features which meet the requirements of inventive step over the disclosure of **D2** combined with the knowledge of the person skilled in the art.

Re Item VII

Certain defects in the application

The relevant background art disclosed in documents **D1-D6** is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the application

Claim 32 is not clear: it is a method claim dependent on a system claim.