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(54) **CONTROL SYSTEM AND METHOD FOR MONITORING THE INTEGRITY OF THE RAILS OF A RAILWAY TRACK**

(57) A control system (100) and a method (200) for monitoring the integrity of the rails (A, B) of a railway track (1), wherein a first sensor (10) and a second sensor (11) are positioned close to each other in proximity of a first rail (A) of the railway track (1) and are configured to detect, independently from each other, a first parameter indicative of the intensity of a current (I_A) flowing along the first rail (A) and to provide to at least one control and processing unit (30) first signals ($S1_{det}$) and respective second signals ($S2_{det}$) indicative of the actual value respectively detected for the first parameter; a third sensor (20) and a fourth sensor (21) are positioned close to each other in proximity of a second rail (B) of the railway track (1) and are configured to detect, independently from each other, a second parameter indicative of the intensity of a current (I_B) flowing along the second rail (B) and to provide to the at least one control and processing unit (30) third signals ($S3_{det}$) and respective fourth signals ($S4_{det}$) indicative of the actual value respectively detected for the second parameter. The at least one control and processing unit (30) is configured to calculate a first value indicative of the intensity (I_A) of the current flowing along the first rail (A) based on at least one of the first and second signals ($S1_{det}$, $S2_{det}$) received from the first and second sensors (10, 11), and a second value indicative of the intensity (I_B) of the current flowing along the second rail (B) based on at least one of the third and fourth signals ($S3_{det}$, $S4_{det}$) received from the third and fourth sensors (20, 21). The at least one control and processing unit (30) is further configured to calculate the difference between the first and second values calculated and to generate a control signal (S_c) indicative of a defective part of one of the first and second rails (A, B) if the difference calculated exceeds a predetermined threshold.

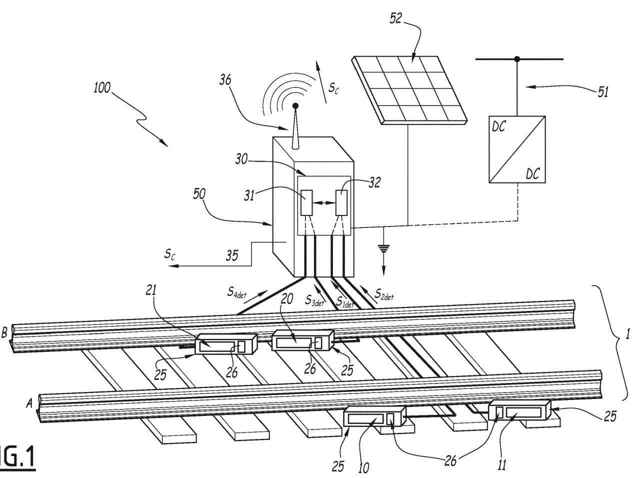

FIG.1

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Description

[0001] The present invention relates to a control system and a method for monitoring the integrity of the rails of a railway track.

[0002] As known, in the field of railways transportation, the requirement of safety is of outmost importance and it is therefore mandatory that the various parts involved in the operations are installed and maintained at the adequate standard of efficiency.

[0003] To this end, the rails play a fundamental role and for them the risk of having defective parts is intrinsic and substantially unavoidable, for instance due to the working conditions under which they are used, e.g. climatic conditions which are usually variable and in some cases might be very harsh, or due to mechanical stresses, for example due to the friction and weight exerted by the travelling vehicles, or just due to the usual aging and mechanical wearing occurring during lifetime service, et cetera.

[0004] As a consequence, a rail may incur in different types of defects, such as superficial defects, hot spots, cracks, breakages, et cetera.

[0005] The occurrence of such defective conditions is usually not instantaneous and in any case it is important that the onset of any defective part or condition is detected as timely and as precisely as possible in order to introduce corrective actions and prevent malfunctioning or failures that could result in long and unacceptable perturbations, or even disruptions, of the railway traffic.

[0006] Some solutions currently used for monitoring the integrity of a rail foresee the use of vehicles provided with specific equipment mounted on board in order to carry out the inspection.

[0007] For example, some vehicles are provided with on board cameras that capture images of the lines, which images are later on examined to identify possible defects; clearly, this solution can identify only superficial defects and is highly influenced by the visibility conditions.

[0008] In order to detect possible defective parts inside the structure of a rail, some other solutions carry out for example vibration tests.

[0009] In particular, these solutions imply the use of devices that are brought into direct contact with a point of a rail where ultrasonic sound waves are injected into the rail; then, the response of the structure, in terms of vibrations, is sensed at a second point of the rail and thereafter analysed.

[0010] In such solutions, the distance between the two points may influence the results; further, the testing operations should be carried out when there are not vehicles travelling along the railway line under inspection or nearby, otherwise the results can be negatively influenced by their disturbances; for example, even the inspection vehicle carrying out a test may introduce undesired vibrations in the rail under testing.

[0011] Yet other solutions foresee the use of track circuits or other suitable dedicated sensors that are positioned along the railway tracks and are meant to provide monitoring signals indicative of the actual condition of the monitored rails.

[0012] Although such solutions allow monitoring somehow the integrity of the rails, they can suffer reliability problems, due for example to the influence of environmental conditions, negatively affecting the detecting capabilities and accuracy of the sensors used, thus impacting the level of safety of the railway operations or causing inappropriate alarms.

[0013] Hence, it is a main aim of the present invention to provide a solution able to mitigate at least partially at least some of the above mentioned drawbacks.

[0014] Within this aim, an object of the present invention is to provide a solution capable of properly monitoring the integrity of the rails of a railway track with a reliability substantially improved over known solutions.

[0015] Another object of the present invention is to provide a solution capable of properly monitoring the integrity of the rails of a railway track while meeting at the same time the highest level of safety integrity level ("SIL"), such as for example the requirements of a SIL4 system.

[0016] Yet a further object of the present invention is to realize a solution capable of properly monitoring the integrity of the rails of a railway track which is relatively easy to be realized at a competitive costs, and which can be applied without any modification or at most with simple modifications to railway lines of different types, be them non-electrified lines, AC or DC electrified lines, railway lines with a high or a low- traffic density.

[0017] The above mentioned aim and objects, as well as any other which may become apparent hereinafter, are achieved by a control system for monitoring the integrity of the rails of a railway track, characterized in that it comprises:

- at least one control and processing unit;
- a first sensor and a second sensor which are positioned close to each other in proximity of a first rail of the railway track, said first and second sensors being configured to detect, independently from each other, a first parameter indicative of the intensity of a current flowing along said first rail and to provide to the at least one control and processing unit first signals and respective second signals indicative of the actual value respectively detected for said first parameter;
- a third sensor and a fourth sensor which are positioned close to each other in proximity of a second rail of the railway track, said third and fourth sensors being configured to detect, independently from each other, a second parameter indicative of the intensity of a current flowing along the second rail and to provide to the at least one control and processing unit third signals and respective fourth signals indicative of the actual value respectively detected for said second parameter;

and wherein the at least one control and processing unit is configured to calculate a first value indicative of the intensity of said current flowing along the first rail based on at least one of the first and second signals received from the first and second sensors, and a second value indicative of the intensity of said current flowing along the second rail based on at least one of the third and fourth signals received from the third and fourth sensors, and wherein the at least one control and processing unit is further configured to calculate the difference between the first and second values calculated and to generate a control signal indicative of a defective part of one of the first and second rails if the difference calculated exceeds a predetermined threshold.

[0018] According to some embodiments, the control system according to the present invention may comprise one or more of the following features, which may be combined in any technical feasible combination:

- the first and second sensors are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the first rail by said current flowing along said first rail, and said third and fourth sensors are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the second rail by said current flowing along said second rail;
- the first sensor and the third sensor are substantially equal to each other and said second sensor and said fourth sensor are substantially equal to each other and of a type different from said first and third sensors;
- the first sensor and the third sensor are Hall-effect sensors;
- the second sensor and the fourth sensor are magneto-resistive sensors;
- one or more of the first, second third and fourth magnetic field sensors are positioned each inside a respective magnetic flux concentrator;
- the control system further comprises at least one test device which is positioned along the railway track and is configured to generate a test current to be injected inside said first and second rails of the railway track;
- the at least one test device comprises a power harvesting unit for self-powering the at least one test device;
- the at least one control and processing unit is housed inside a control station which is positioned along the railway track and comprises a power harvesting unit for powering at least said one control and processing unit;
- the at least one control and processing unit comprises a first control and processing unit and a second control and processing unit, wherein the first control and processing unit is arranged to be connected to and receive signals from one of the first and second sensors and one of the third and fourth sensors, and the second control and processing unit is arranged to be connected to and receive signals from the other one of the first and second sensors and the other one of the third and fourth sensors.

[0019] The above mentioned aim and objects, as well as any other which may become apparent hereinafter, are achieved by a method for monitoring the integrity of the rails of a railway track, characterized in that it comprises at least the following steps:

- (a): detecting, by means of a first sensor and of a second sensor which are positioned close to each other in proximity of a first rail of the railway track, independently from each other, a first parameter indicative of the intensity of a current flowing along said first rail and providing to at least one control and processing unit first signals and respective second signals indicative of the actual value respectively detected for said first parameter;
- (b): detecting, by means of a third sensor and of a fourth sensor which are positioned close to each other in proximity of a second rail of the railway track, independently from each other, a second parameter indicative of the intensity of a current flowing along said second rail of the railway track and providing to said at least one control and processing unit third signals and respective fourth signals indicative of the actual value respectively detected for said second parameter; and, by means of said at least one control and processing unit:
- (c): calculating, a first value indicative of the intensity of said current flowing along the first rail based on at least one of the first and second signals received from the first and second sensor, and a second value indicative of the intensity of said current flowing along the second rail based on at least one of the third and fourth signals received from the third and fourth sensor;
- (d): calculating, the difference between the calculated first and second values;
- (e): generating a control signal indicative of a defective part of one of the first and second rails if the calculated difference exceeds a predetermined threshold.

[0020] Further characteristics and advantages will become apparent from the description of some preferred but not exclusive exemplary embodiments of a system and a method according to the invention, illustrated only by way of non-limitative examples with the accompanying drawings, wherein:

Figure 1 is a view schematically illustrating an example of a control system according to the invention applied to the rails of a railway track;

Figure 2 schematically shows a couple of sensors of the control system of figure 1 positioned along a rail of a railway track;

Figure 3 is a schematic circuital representation of a possible embodiment of a control system according to the present invention comprising a test device;

Figure 4 schematically shows a circuital exemplary embodiment of a test device usable in the control system according to the invention;

Figure 5 is a flow chart illustrating a method for monitoring the integrity of the rails of a railway track according to the invention.

[0021] It should be noted that in order to clearly and concisely describe the present disclosure, the drawings may not necessarily be to scale and certain features of the disclosure may be shown in somewhat schematic form.

[0022] Further, when the term "adapted" or "arranged" or "configured" or "shaped", is used herein while referring to any component as a whole, or to any part of a component, or to a combination of components, it has to be understood that it means and encompasses correspondingly either the structure, and/or configuration and/or form and/or positioning.

[0023] In particular, for electronic and/or software means, each of the above listed terms means and encompasses electronic circuits or parts thereof, as well as stored, embedded or running software codes and/or routines, algorithms, or complete programs, suitably designed for achieving the technical result and/or the functional performances for which such means are devised.

[0024] When the terms transversal or transversally are hereby used, they have to be understood as encompassing a direction non-parallel to the part(s) they refer to, and perpendicularity has to be considered a specific case of transverse direction.

[0025] In addition, when the terms substantial or substantially are used with reference to moving parts, e.g. two parts moving substantially solidly to each other, it has to be understood that they move together apart from unavoidable mechanical inertia, while when referring to relative positioning, e.g. one part substantially parallel to another part, it has to be understood as encompassing a tolerance of plus or minus 5°.

[0026] Finally, in the following description and claims, the numeral cardinals first, second, third et cetera..., will be used only for the sake of clarity of description and in no way they should be understood as limiting for whatsoever reason. In particular, the indication of a component referred to for instance as the "third..." does not imply necessarily the presence or strict need of the preceding "first" or "second" ones, unless such presence is clearly evident for the correct functioning of the subject embodiment(s), nor that the order should be the one described in the illustrated exemplary embodiment(s); further, when using the terms first, second, et cetera, while referring for example to a first parameter and to a second parameter, such distinction is used primarily for clarity purposes and the two parameters may be the same or different, depending on and as it can be inferred from the context they are used.

[0027] Figure 1 schematically illustrates a possible embodiment of a control system according to the invention, indicated therein by the overall reference number 100, which is suitable to monitor the integrity of the two rails A and B of a railway track, indicated in figure 1 by the reference number 1.

[0028] The control system 100 comprises at least:

- at least one control and processing unit, schematically indicated in figure 1 by the reference number 30;
- a first sensor 10 which is positioned in proximity of a first rail A of the railway track 1, i.e. at a certain distance from the surface of the first rail A, as for example illustrated in figure 2. In particular the first sensor 10 is configured to detect, preferably in a contactless manner, a first parameter indicative of the intensity of a current I_A flowing along the first rail A and to provide to the at least one control and processing unit 30, first signals $S1_{det}$ indicative of the actual value detected by itself for the first parameter;
- a second sensor 11 which is positioned in proximity of the first rail A and close to the first sensor 10, likewise at a certain distance from the surface of the first rail A, as for example illustrated in figure 2. The second sensor 11 is configured to detect, independently from the first sensor 10, preferably in a contactless manner with respect to the first rail ail A, the same first parameter indicative of the intensity of said current I_A flowing along the first rail A and to provide to the at least one control and processing unit 30 respective second signals $S2_{det}$ indicative of the actual value detected by itself for the first parameter;
- a third sensor 20 which is positioned in proximity of a second rail B of the railway track 1, i.e. at a certain distance from the surface of the second rail B, in a manner similar for example to that of the first sensor 10 relative to the first rail A. The third sensor 20 is configured to detect, preferably in a contactless manner, a second parameter indicative of the intensity of a current I_B flowing along the second rail B and to provide to the at least one control and processing unit 30, third signals ($S3_{det}$) indicative of the actual value detected by itself for the second parameter; and
- a fourth sensor 21 which is positioned in proximity of the second rail B close to the third sensor 20, e.g. at a certain distance from the surface of the second rail B, for example with respect to the third sensor 20 and the second rail B, similarly to the positioning of the second sensor 11 relative to the first sensor 10 and to the first rail A illustrated in figure 2. The fourth sensor 21 is configured to detect, independently from the third sensor 20, preferably in a contactless manner with respect to the second rail B, the same second parameter indicative of the intensity of said current I_B flowing along the second rail

B, and to provide to the at least one control and processing unit 30 fourth signals $S4_{det}$ indicative of the actual value detected by itself for the second parameter.

[0029] In the control system 100 according to the invention, the at least one control and processing unit 30 is configured to calculate:

- a first value indicative of the intensity of the current I_A flowing along the first rail A based on at least one of the first signals $S1_{det}$ and the second signals $S2_{det}$ received from the first and second sensors 10, 11 and carrying information relative to the value of the first parameter actually detected by them: and
- a second value indicative of the intensity of the current I_B flowing along the second rail B based on at least one of the third signals $S3_{det}$ and the fourth signals $S4_{det}$ received from the third and fourth sensors 20 and 21, and carrying information relative to the value of the second parameter actually detected by them.

[0030] Conveniently, in the control system 100 according to the invention, the at least one control and processing unit 30 is further configured to calculate the difference between the first and second values calculated and to generate a control signal S_c indicative of a defective part along one of the first and second rails A, B if the difference calculated exceeds a predetermined threshold.

[0031] The control signal S_c can be sent for example, via transmissions cables 35, or via a wireless device, such as the exemplary one illustrated in figure 1 by the reference number 36, towards a remote control center overseeing an entire railway line to which the monitored railway track 1 belongs to.

[0032] Likewise, each of the first, second, third and fourth sensors 10, 11, 20 and 21 can provide the respective signals to the at least one control and processing unit 30, via a cabled connections 15 or in a wireless manner.

[0033] In one possible embodiment, the first and second sensors 10 and 11 are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the first rail A by a current I_A flowing along the first rail A itself.

[0034] Likewise, the third and fourth sensors 20 and 21 are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the second rail B by a current I_B flowing along the second rail B itself.

[0035] The magnetic field lines around the rails A or B are schematically represented in figure 2 by the arrows 5.

[0036] In one possible embodiment of the control system 100, the first sensor 10 operatively associated to the first rail A and the third sensor 20 operatively associated to the second rail B are substantially equal to each other; in turn, the second sensor 11 operatively associated to the first rail A and the fourth sensor 21 operatively associated to the second rail B are substantially equal to each other and of a type different from the first and third sensors 10 and 20.

[0037] In practice, in the control system 100, there are conveniently used two couples of sensors, out of which a first couple is based on a first type of physical properties or detecting technology in order to detect a parameter indicative of the actual current flowing in the rails A and B, and a second couple is based on a second type of physical properties or detecting technology in order to detect a parameter indicative of the actual current flowing in the rails A and B.

[0038] In the embodiment illustrated, the first and second parameters detected are the same, i.e. the intensity of the magnetic fields generated around the first rail A and correspondingly around the second rail B by the current I_A flowing along the first rail A and respectively the current I_B flowing along the second rail B.

[0039] In one possible embodiment, the first sensor 10 and the third sensor 20 are Hall-effect sensors.

[0040] In turn, according to a possible embodiment, the second sensor 11 and the fourth sensor 21 are magneto-resistive sensors.

[0041] In this way, with respect to known solutions, the overall reliability of the control system is improved, and it is possible to mitigate the negative influence of perturbations and to reduce the need of testing the sensors used.

[0042] Indeed, by having sensors working according to different principles, it can be safely assumed that an external influence would result in different behaviors by the two types of sensors, and therefore such perturbing influence can be better identified as such and based on the diversity of the sensors.

[0043] Further, each of the first, second, third and fourth sensors 10, 11, 20 and 21, can be positioned inside a respective casing, illustrated schematically in figure 1 by the reference number 25; for instance, each casing 25 can be conveniently dust and water proof and, depending on the applications, it can be also realized with a material suitable to shield external disturbing magnetic fields if needed.

[0044] According to a possible embodiment, one or more of, preferably all the first, second third and fourth magnetic field sensors 10, 11, 20 and 21 are positioned each inside a respective magnetic flux concentrator, schematically indicated in figure 1 by the reference number 26.

[0045] In one possible embodiment, and as illustrated in figure 1, the control system 100 comprises a control station 50 housing inside the at least one control and processing unit 30.

[0046] In particular, the control station 50 is positioned along the railway track 1, for example substantially at the same position where the first, second, third and fourth sensors 10, 11, 20 and 21 are positioned.

[0047] If the railway track 1 is part of an electrified line, for example a railway line powered by a catenary line schematically illustrated in figure 1 by the reference number 51, the at least one control and processing unit 30 and the associated first, second, third and fourth sensors 10, 11, 20 and 21 can be supplied via power derived from the catenary line 51 itself; the same applies if the railway track 1 is powered by an AC source.

[0048] Alternatively, in particular if the railway track 1 to be monitored is part of a non-electrified line, the control station 50 comprises a power harvesting system 52, comprising for example one or more solar panels and related electronics, which is configured to harvest power, e.g. for powering the at least one processing unit 30 and also the associated first, second, third and fourth sensors 10, 11, 20 and 21.

[0049] According to an alternative embodiment, the first, second, third and fourth sensors 10, 11, 20 and 21 may comprise or be coupled with dedicated power harvesting devices configured to harvest power and supply each one or more of such sensors.

[0050] According to a further possible embodiment, the control system 100 according to the invention further comprises at least one test device 40 which is positioned along the railway track 1 and is configured to generate a test current to be injected inside the first and second rails A, B of the railway track 1 in order to monitor their integrity.

[0051] For example, the test device 40 can be housed also inside the control station 50.

[0052] According to this embodiment, the currents injected in the rails A and B by the test device 40 are those generating the magnetic fields detected by the first, second, third and fourth sensors indicated by the reference numbers 80, 81, 90 and 91 whose signals are then received by the at least control and processing unit 30 and properly processed, as previously described, in order to verify any defective part present along the first rail A or the second rail B.

[0053] Each sensor 80, 81, 90 and 91 can be a single sensor of the same kind as 10, 11, 20 or 21 if redundancy is not required; otherwise for each of sensor 80, 81, 90 and 91 for example a couple of a Hall effect sensor and a magnetoresistive sensor can be used, since it is not known "a priori" in which direction relative to power stations 101 the test current will flow; hence, in this last case a total of eight sensors will be used.

[0054] The test device 40 can be realized according to various possible circuital schemes, per se known or readily available to those skilled in the art, and thus not described herein in further details, according to two main reference schemes different from each other based on the fact whether the test device 40 is used in a railway track which is already electrified and therefore a voltage source is available or not, in which case the test device 40 comprises also an own power generator.

[0055] Basically, the test device can be realized as a variant of a buck or buck-boost high frequency switching power converter, configured to output a current, as for example illustrated in figure 4, where there is depicted a circuital exemplary embodiment for such test device 40.

[0056] In this exemplary embodiment, the upper switch 41 is PWM-modulated via a pulse generator or PWM modulator 42 so that the average current injected in the rails A and B is maintained at a certain level. The current comes from a remote traction power station through the catenary line 51, and returns to it through the rails A and B, in particular one half for each rail. The duty cycle of the switch 41 is kept very low to keep conduction losses at a minimum, and to use a high frequency current transformer 43 which is connected in series with an inductor 44 to sense the current and use the relative signal S_F as feedback for the pulse generator or PWM modulator 42. The switch 41 can be realized with an appropriate cascade connection of high voltage, low power SiC IGBT or Mosfet, of any suitable type currently available on the market, connected in series to the current transformer 43 and the inductor 44, in order to realize the switch 41. In the exemplary embodiment of figure 4, diodes 45 are connected in parallel to the assembly formed by the serial connection of the inductor 44 and the transformer 43. Diodes 45 are an appropriate cascade connection of high voltage SiC diodes of any suitable type currently available on the market.

[0057] The reference signal for the PWM modulator 42 can be a fixed one, or - better - a low frequency coded one, so that the injected current can vary between two or more levels, following a predefined pattern or a pattern generated by the electronics of the associated detection system.

[0058] The test current generated in this way is equivalent to the current drawn by the train; the currents in the rails will be measured by the two pair of sensors and their differential evaluated to asses if the rails are in good conditions or not.

[0059] If the control system 100 is used in an electrified railway track 1, as in the schematic example above illustrated, the power needed to generate the currents to be injected into the rails A and B can be provided for example by one traction power station 101 used for powering the track 1 itself; in such cases, the test device 40 can be placed along the railway track 1 in the centre of the electric "line" between two traction power stations 101, as illustrated in figure 3.

[0060] Alternatively, if for example the railway track is not electrified, the test device 40 can comprise an own power harvesting unit, indicated schematically in figure 3 by the dotted box 48, which is configured to harvest and store power to be used for self-powering, or it can be powered by the power harvesting system 52 of the control station 50.

[0061] The test device 40 can be conveniently used to monitor the integrity of the rails A and B of a railway track 1, either when the railway track 1 is part of a non-electrified line, and/or where the majority of trains travelling along the track 1 are not electric ones, and/or there are long intervals of time without passages of trains.

[0062] In particular, the presence of a test device 40 allows performing monitoring of the rails with any sufficient frequency of monitoring tests necessary for example to meet SIL4-type requirements.

[0063] Conveniently, in one embodiment of the control system 100 according to the present invention, the at least one control and processing unit 30 comprises a first control and processing unit 31 and a second control and processing unit 32, schematically represented in figure 1 by the reference numbers 31 and 32, respectively.

[0064] In particular, the first control and processing unit 31 is arranged to be operatively connected to and receive the signals indicative of the corresponding magnetic field detected from one of the first and second sensors 10 and 11, and from one of the third and fourth sensors 20, 21 of different type, while the second control and processing unit 32 is arranged to be operatively connected to and receive signals indicative of the corresponding magnetic field detected from the other one of the first and second sensors 10, 11 and from the other one of the third and fourth sensors 20 and 21 having a different type.

[0065] For example, as illustrated in figure 1, the first control and processing unit 31 can receive the signals $S1_{det}$ and S4de, from the Hall-effect sensor 10 and the magneto-resistive sensor 21, while the second control and processing unit 31 can receive the signals $S2_{det}$ and $S3_{det}$ from the magneto-resistive sensor 11 and the Hall-effect sensor 20.

[0066] Clearly, other alternative operative connections are possible; for example, one of the first and second control and processing units 31 and 32 can receive the signals provided by the Hall-effect sensors, and the other one can receive only the signals from the magneto-resistive sensors.

[0067] The presence of the two control and processing units 31 and 32 improves redundancy, reliability and robustness of the control system 100.

[0068] In particular, if for whatever reason, the environment around the sensors "perturbates' the reading of one type of sensor, e.g. a Hall-effect sensor or both Hall-effect sensors, the other ones, e.g. the magneto-resistive sensors will continue to detect the magnetic fields correctly, and at least one of the control and processing units 31 and 32, exchanging data between them, would be able to detect anyhow the presence of a defective part on a rail A or B, and generate a corresponding control signal S_C.

[0069] In particular, the two control and processing units 31 and 32 can be mutually coordinated to follow an appropriate and coordinated decisional process in order to solve any conflicting computation between them and properly discriminate among inconsistent detections, due for example to an actual external perturbation versus an actual malfunctioning of any sensor; for example, references values for the currents I_A and I_B can be prerecorded and taken as reference, for example on the basis of a nominal behavior for the railway track 1, or based on precalibration/autocalibration tests, or on periodic calibration tests executed injecting known currents, e.g. via the test device 40.

[0070] In figure 5 there is schematically illustrated a method 200 for monitoring the integrity of the rails A, B of a railway track 1, which can be implemented for example by a control system as previously described.

[0071] In particular, the method 200 comprises at least the following steps:

- 210: detecting, by means of a first sensor and of a second sensor, e.g. the two sensors 10 and 11, which are positioned close to each other in proximity of a first rail A of the railway track 1, independently from each other, preferably in a contactless manner with respect to the first rail 1, a first parameter indicative of the intensity of a current I_A flowing along the first rail A and providing to at least one control and processing unit, such as the control and processing unit 30, first signals $S1_{det}$ and respective second signals $S2_{det}$ indicative of the actual value respectively detected for said first parameter by the two sensors;
- 220: detecting, by means of a third sensor and of a fourth sensor, e.g. the sensors 20 and 21, which are positioned close to each other in proximity of a second rail B of the railway track 1, independently from each other, preferably in a contactless manner with respect to the second rail B, a second parameter indicative of the intensity I_B of a current flowing along the second rail B of the railway track 1, and providing to the at least one control and processing unit, e.g. the unit 30, third signals $S3_{det}$ and respective fourth signals $S4_{det}$ indicative of the actual value respectively detected for said second parameter by these two other sensors 20 and 21; and, by means of the at least one control and processing unit, such as the unit 30:
- 230: calculating, a first value I_A indicative of the intensity of said current flowing along the first rail A based on at least one of the first and second signals $S1_{det}$, $S2_{det}$ received from the first and second sensor 10, 11, and a second value I_B indicative of the intensity of the current flowing along the second rail B based on at least one of the third and fourth signals $S3_{det}$, $S4_{det}$ received from the third and fourth sensors 20 and 21;
- 240: calculating, the difference between the calculated first and second values I_A and I_B;
- 250: generating a control signal indicative of a defective part of one of the first and second rails A, B if the calculated difference exceeds a predetermined threshold.

[0072] As those skilled in the art would readily appreciate, the steps of detecting 210 and 220 can be executed in parallel to each other or in whatever suitable sequence.

[0073] Further, the method 200 can implement all steps and sub-steps corresponding to the execution of the various functionalities and performances described above for the control system 100, which are not hereby replicated for the sake of conciseness.

[0074] It is evident from the foregoing description and appended claims that the control system 100 and method 200 according to the present invention, achieve the intended aim and objects, since they allow detecting, timely and precisely, the presence of a potentially defective part of any part of a rail, according to a solution having an increased reliability and which improves therefore the overall safety of railway operations along the railway track 1 thus monitored.

[0075] These results are achieved according to a solution relatively easy to realize and very flexible that can be implemented in railway lines which are electrified, either with DC of AC power sources, and non-electrified ones as well.

[0076] The system 100 and method 200 thus conceived are susceptible of modifications and variations, all of which are within the scope of the inventive concept as defined in particular by the appended claims; for example, the control system 100 may comprise a plurality of control stations 50 distributed at a certain distance from each other along a railway line and each of the control station can be associated with two couples of sensors of different type as previously described; the control and processing unit 30, or each of the two control and processing units 31 and 32 can be constituted by, or comprise, any suitable processor-based device, e.g. a processor of a type commercially available, suitably programmed and provided to the extent necessary with circuitry, in order to perform the innovative functionalities devised for the control system 100 according to the present invention.

[0077] All the details may furthermore be replaced with technically equivalent elements.

Claims

1. A control system (100) for monitoring the integrity of the rails (A, B) of a railway track (1), **characterized in that** it comprises:

   - at least one control and processing unit (30);
   - a first sensor (10) and a second sensor (11) which are positioned close to each other in proximity of a first rail (A) of the railway track (1), said first and second sensors (10, 11) being configured to detect, independently from each other, a first parameter indicative of the intensity of a current (I_A) flowing along said first rail (A) and to provide to the at least one control and processing unit (30) first signals ($S1_{det}$) and respective second signals ($S2_{det}$) indicative of the actual value respectively detected for said first parameter;
   - a third sensor (20) and a fourth sensor (21) which are positioned close to each other in proximity of a second rail (B) of the railway track (1), said third and fourth sensors (20, 21) being configured to detect, independently from each other, a second parameter indicative of the intensity of a current (I_B) flowing along the second rail (B) and to provide to the at least one control and processing unit (30) third signals ($S3_{det}$) and respective fourth signals ($S4_{det}$) indicative of the actual value respectively detected for said second parameter;

   and wherein the at least one control and processing unit (30) is configured to calculate a first value indicative of the intensity (I_A) of said current flowing along the first rail (A) based on at least one of the first and second signals ($S1_{det}$, $S2_{det}$) received from the first and second sensors (10, 11), and a second value indicative of the intensity (I_B) of said current flowing along the second rail (B) based on at least one of the third and fourth signals ($S3_{det}$, $S4_{det}$) received from the third and fourth sensors (20, 21), and wherein the at least one control and processing unit (30) is further configured to calculate the difference between the first and second values calculated and to generate a control signal (S_c) indicative of a defective part of one of the first and second rails (A, B) if the difference calculated exceeds a predetermined threshold.

2. A control system (100) according to claim 1, wherein said first and second sensors (10, 11) are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the first rail (A) by said current (I_A) flowing along said first rail (A), and said third and fourth sensors (20, 21) are magnetic field sensors configured to sense values indicative of an actual magnetic field generated around the second rail (B) by said current (I_B) flowing along said second rail (B).

3. A control system (100) according to claim 1 or 2, wherein said first sensor (10) and said third sensor (20) are substantially equal to each other and said second sensor (11) and said fourth sensor (21) are substantially equal to each other and of a type different from said first and third sensors (10, 20).

4. A control system (100) according to claim 3, wherein said first sensor (10) and said third sensor (20) are Hall-effect sensors.

5. A control system (100) according to claim 3, wherein said second sensor (11) and said fourth sensor (21) are magneto-resistive sensors.

6. A control system (100) according to claim 2, wherein one or more of said first, second third and fourth magnetic field sensors (10, 11, 20, 21) are positioned each inside a respective magnetic flux concentrator

(26).

7. A control system (100) according to one or more of the previous claims, wherein it further comprises at least one test device (40) which is positioned along the railway track (1) and is configured to generate a test current to be injected inside said first and second rails (A, B) of the railway track (1).

8. A control system (100) according to claim 7, wherein said at least one test device (40) comprises a power harvesting unit (52) for self-powering the at least one test device (40).

9. A control system (100) according to one or more of the previous claims, wherein said at least one control and processing unit (30) is housed inside a control station (50) which is positioned along the railway track (1) and comprises a power harvesting unit (52) for powering at least said one control and processing unit (30).

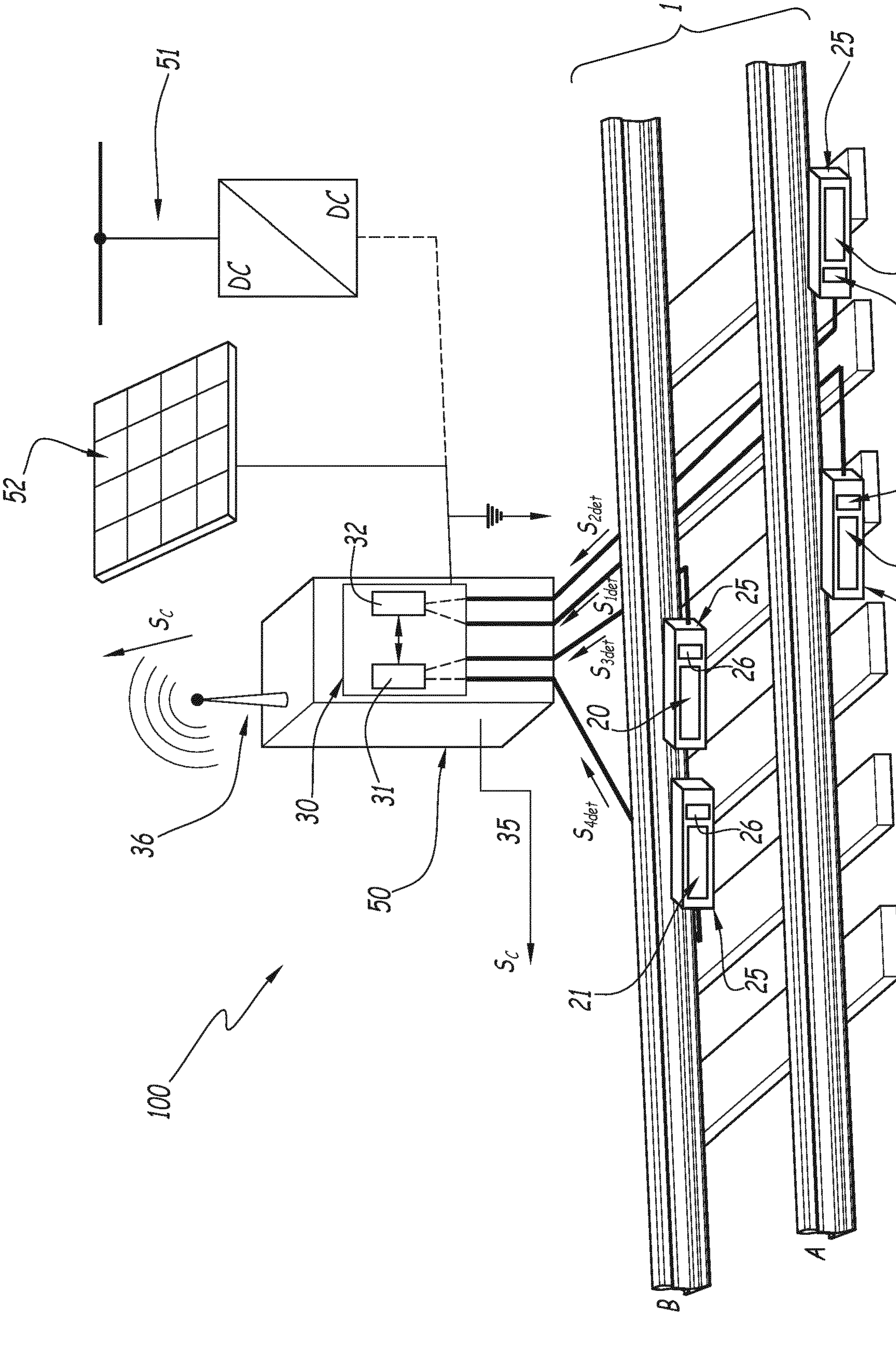
10. A control system (100) according to one or more of the previous claims, wherein said at least one control and processing unit (30) comprises a first control and processing unit (31) and a second control and processing unit (32), and wherein the first control and processing unit (31) is arranged to be connected to and receive signals from one of the first and second sensors (10, 11) and one of the third and fourth sensors (20, 21), and wherein the second control and processing unit (32) is arranged to be connected to and receive signals from the other one of the first and second sensors (10, 11) and the other one of the third and fourth sensors (20, 21).

11. A method (200) for monitoring the integrity of the rails (A, B) of a railway track (1), **characterized in that** it comprises at least the following steps:

- (210): detecting, by means of a first sensor (10) and of a second sensor (11) which are positioned close to each other in proximity of a first rail (A) of the railway track (1), independently from each other, a first parameter indicative of the intensity of a current (I_A) flowing along said first rail (A) and providing to at least one control and processing unit (30) first signals ($S1_{det}$) and respective second signals ($S2_{det}$) indicative of the actual value respectively detected for said first parameter;
- (220): detecting, by means of a third sensor (20) and of a fourth sensor (21) which are positioned close to each other in proximity of a second rail (B) of the railway track (1), independently from each other, a second parameter indicative of the intensity of a current (I_B) flowing along said second rail (B) of the railway track (1) and providing to said at least one control and processing unit (30) third signals ($S3_{det}$) and respective fourth signals ($S4_{det}$) indicative of the actual value respectively detected for said second parameter;

and, by means of said at least one control and processing unit (30)

- (230): calculating, a first value indicative of the intensity (I_A) of said current flowing along the first rail (A) based on at least one of the first and second signals (($S1_{det}$, $S2_{det}$) received from the first and second sensor (10, 11), and a second value indicative of the intensity (I_B) of said current flowing along the second rail (B) based on at least one of the third and fourth signals ($S3_{det}$, $S4_{det}$) received from the third and fourth sensor (20, 21);
- (240): calculating, the difference between the calculated first and second values;
- (250): generating a control signal indicative of a defective part of one of the first and second rails (A, B) if the calculated difference exceeds a predetermined threshold.


1
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51
DC
DC
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11
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S2det
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S3det
S4det
Sc
10
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20
26
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36
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31
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50
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21
25
100
B
A

FIG.1

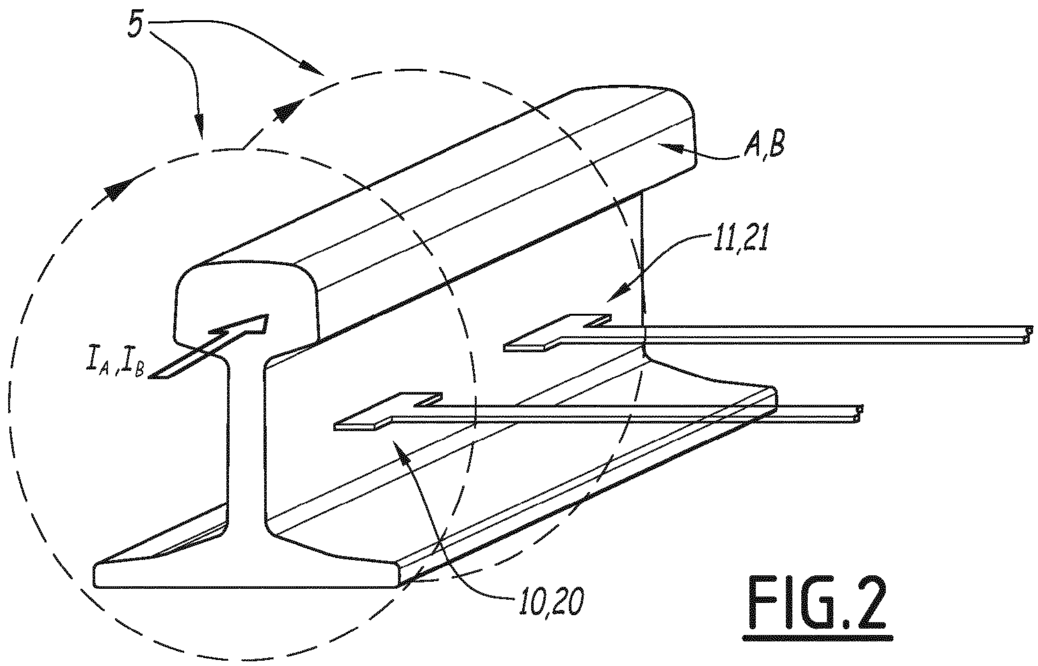

FIG.2

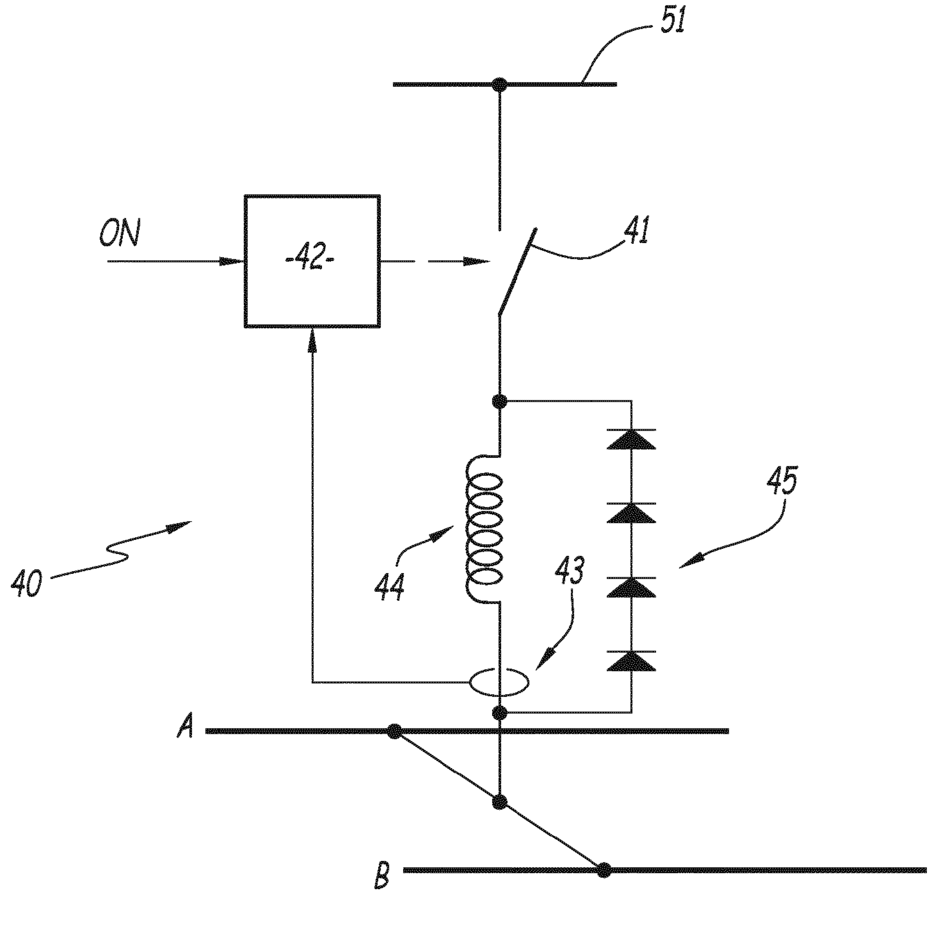

FIG.4

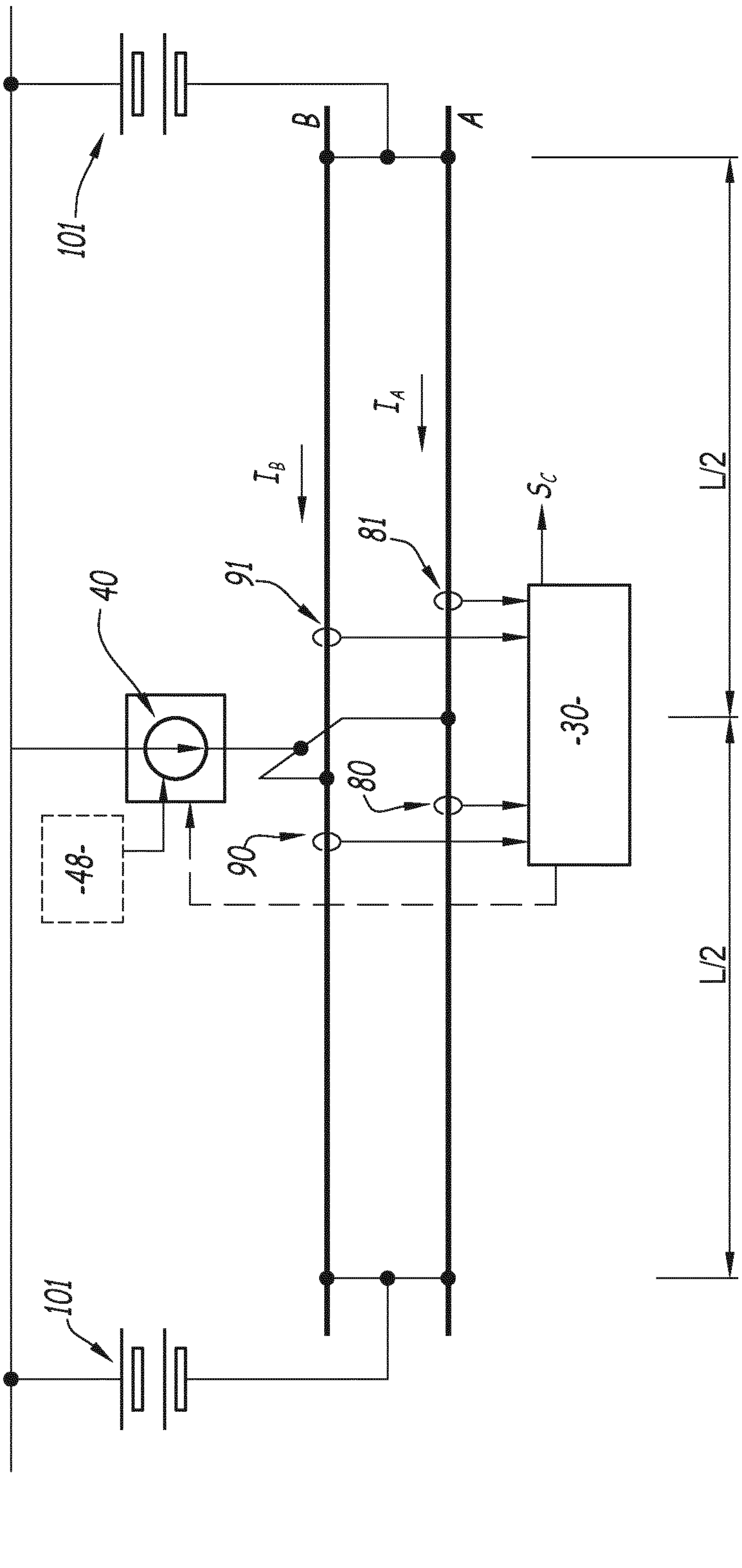

FIG.3

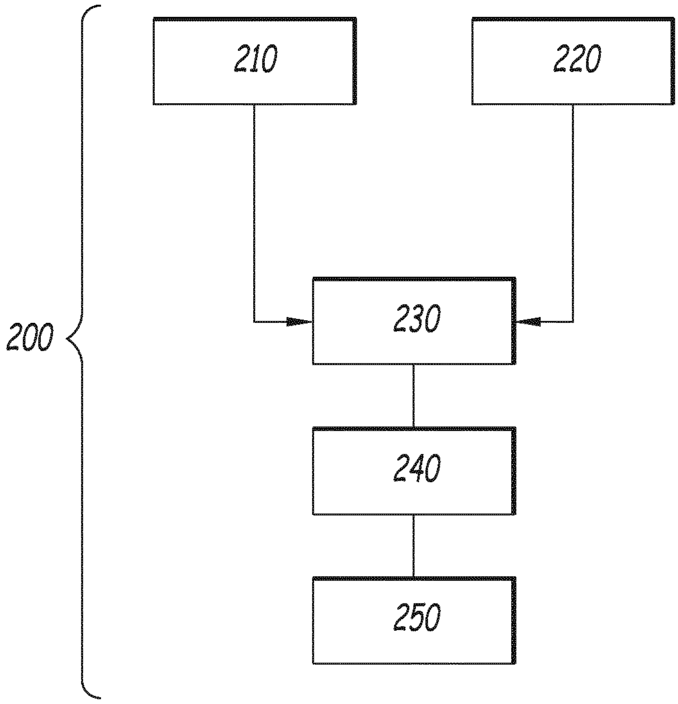

FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 20 30 5986

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	DE 10 2006 009962 B3 (AREVA NP GMBH [DE]) 31 May 2007 (2007-05-31) * abstract; figures 1,3,7,8 * * paragraphs [0007] - [0009] * * paragraphs [0019] - [0024] * * paragraphs [0026], [0028] - [0031] *	1,2,6,7, 9-11 3-5 8	INV. B61L23/04 B61L27/00 B61L1/18
X	US 2011/006167 A1 (TOLMEI RON [US]) 13 January 2011 (2011-01-13) * abstract; figure 1 * * paragraphs [0012], [0015] * * paragraphs [0022] - [0024] *	1,7,10, 11	
Y	WEI YANG ET AL: "A residual current measurement method with a combination of MR and Hall Effect sensors", APPLIED MEASUREMENTS FOR POWER SYSTEMS (AMPS), 2010 IEEE INTERNATIONAL WORKSHOP ON, IEEE, PISCATAWAY, NJ, USA, 22 September 2010 (2010-09-22), pages 27-30, XP031780642, ISBN: 978-1-4244-7372-4 * Sections II and III; figures 2-4 *	3-5	TECHNICAL FIELDS SEARCHED (IPC) B61L

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	19 February 2021	Robinson, Victoria

CATEGORY OF CITED DOCUMENTS

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19-02-2021

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82